# The AMSAT® Journal

**Volume 40, Number 1**

**Jan/Feb 2017**

Packet Up!

## in this issue ...

KENWOOD

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Status

ARISS – Interna
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# AMSAT Announcements

## 2017 AMSAT Space Symposium and Annual Meeting

**Silver Legacy Resort, Reno, Nevada**
**October 27-29, 2017**

The annual AMSAT Space Symposium features:

* Space Symposium with Amateur Satellite Presentations
* Operating Techniques, News, & Plans from the Amateur Satellite World
* Board of Directors Meeting open to AMSAT members
* Opportunities to Meet Board Members and Officers
* AMSAT-NA Annual General Membership Meeting
* Auction, Annual Banquet, Keynote Speaker and Door Prizes!

Several members from The Sierra Nevada Amateur Radio Society (SNARS), as well as many other local radio amateurs will be participating in helping with this event.

Additional information about the 2017 AMSAT Symposium will be posted on the AMSAT web site, **www.amsat.org** as it becomes available.

**AMSAT's Mission**
AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

**AMSAT's Vision**
Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.

## Apogee View

### Barry Baines, WD4ASW
### President

Happy New Year! I trust the holiday season was a joyous one for you with good cheer and opportunities to be with friends and family. May 2017 be a wonderful year.

During the holiday season, Kathy (WD4ASX) and I were in the midst of transition, establishing a new household in Keller, TX. We wanted to be near one pair of grandchildren during the fall and winter months. We've gotten to the point where the majority of boxes and packing materials have been recycled, and the residence is starting to feel like "home." We have much yet to do to get the chaos under control, but at least we see some daylight at the end of the tunnel. We're looking forward to becoming more familiar with the Dallas/Ft. Worth Metroplex.

In the spring and summer, we'll be spending time in the Boston area to be near the second pair of grandchildren as we establish a second residence. So the chaos will continue later.

The beginning of the New Year also serves as a kickoff for AMSAT as we transition our focus towards this year's activities. This year promises to be an exciting one for AMSAT with new launches and new venues for two of the most popular gatherings for AMSAT members, Hamvention and Symposium, and ARISS continuing to make huge impacts on education.

## Four Fox-1 Satellite Launches

First, we're looking forward to the launch of four Fox-1 class satellites. NASA has announced that the launch of RadFXSat (Fox-1B) under ELaNa-XIV has been moved to August 29, 2017, as the primary payload (JPSS-1) has been delayed. The Mission Readiness Review is targeting May 1-2 in San Luis Obispo, CA following the Cal Poly CubeSat Workshop in San Luis Obispo. AMSAT has attended the CubeSat Workshop in prior years, and we expect to attend this year's event as well.

Fox-1Cliff and Fox-1D are manifested under an AMSAT contract with Spaceflight, Inc., to fly on a Falcon-IX launch vehicle. SpaceX had a successful launch of the Falcon-IX the week of January 9, 2017, which bodes well for SpaceX to announce both its launch schedule and when we can expect our launch. We think that announcement will come in the very near future.

RadFxSat-2 (Fox-1E) is still scheduled to be launched in December 2017 under ELaNa-XX, though experience suggests that we shouldn't be surprised if this time frame changes. IARU coordination has been filed. Transponder development is coming along well, and the Engineering Team expects the satellite to be completed on schedule.

Along with upcoming launches, we're also planning for two key events in 2017: Hamvention (May 19-22), and the AMSAT Space Symposium and Annual General Meeting. Our Dayton Team Leader is Steve Belter, N9IP, who already is communicating with the Hamvention Exhibit Chairman about AMSAT's booth presence at the new venue and securing an area for our satellite demos led by Paul Stoetzer, N8HM. Steve and his team of volunteers are examining the new commercial exhibit booth layout and coming up with some enhancements to improve AMSAT's presence.

Our initial impression is that the Hamvention leadership is working hard to make the new venue at Greene County Fairgrounds a success. We'll be releasing more information about AMSAT's Hamvention participation in the next couple of months

## Symposium

The 2016 AMSAT Space Symposium @ Sea was a resounding success based on the enthusiasm of the attendees, the number of participants, and the quality of the presentations. Everyone who attended had a great time, and the presence of so many satellite operators with their portable stations operating from the decks of Carnival Liberty was certainly impressive.

Adding to the success was the number of spouses, significant others, and family members who took advantage of the cruise ship venue to come along with their Symposium attendee. I suspect that having a venue with lots of opportunities for non-Symposium participants helped build interest in Symposium itself.

Given the overall success of the 2016 AMSAT Space Symposium @ Sea, where will the 2017 AMSAT Space Symposium & Annual General Meeting take place? And will that location encourage family members to come along as well?

The good news is that AMSAT has selected a location for the 2017 AMSAT Space Symposium & Annual General Meeting: Reno, NV. An ANS announcement about Symposium was included in the ANS released in ANS-22. The event will take

place the weekend of October 27-29, 2017, and the Symposium hotel will be the Silver Legacy Resort, 407 N. Virginia Street in downtown Reno.

The Silver Legacy is a 4-star Resort/Hotel/Casino with a massive round dome and spires centered in downtown. The Silver Legacy is typically lit green at night and is referred to by many as the "Emerald City" of Reno. In support of the University of Nevada Wolf Pack, the Silver Legacy will sometimes turn blue.

As a downtown hotel, the Silver Legacy is close to a variety of restaurants and points of interest including museums and entertainment. If you have time before or after Symposium, other locations to visit include Lake Tahoe and Virginia City.

Please mark your calendar and join AMSAT in Reno the weekend of October 27-29.

By the way, AMSAT-UK will be holding its Colloquium two weeks before our Space Symposium (October 14-15) at a new venue in conjunction with the RSGB Convention at the Kents Hill Park Conference Centre, Timbold Drive, Milton Keynes, MK7 6BZ. If you're interested in learning more about Colloquium, check the AMSAT-UK website (www.amsat-uk.org) for details as they become available. Having both meetings occur in the same month provides an opportunity for amateur satellite operators to participate in two gatherings taking place on two continents focused on amateur radio in space.

## ARISS

If you're an ARRL member, I hope you saw Kenwood's two-page ad in the February 2017 of QST that features their support for ARISS. After spending an evening unpacking boxes and getting things organized, I downloaded the February 2017 issue of QST. I was reviewing the issue when I came across the ad on pp. 30-31. All I can say is "WOW!" The imagery is stunning. I was impressed to see the ARISS logo prominently displayed, and the text in support of ARISS is certainly excellent.

Most importantly, the Kenwood ad asks ARRL members to support ARISS and includes the AMSAT-NA address ("Attn: ARISS Donation") for people to mail their checks and also references the AMSAT website for electronic donations. In a subtle way, this ad recognizes the important role that AMSAT plays with ARISS. Hopefully, this will translate into more web interest for AMSAT as well.

Kenwood's support for ARISS, not only with regard to providing the TM-D710GA and their engineering expertise but now with significant publicity support for fundraising is certainly a welcome effort. Clearly, the efforts of the entire ARISS team in support of education in space is being noticed and, hopefully, that increased awareness also will translate into financial support by ARRL members.

A great way to start the year — an outstanding image and message in QST!

# Ten Things You Probably Didn't Know About Launching CubeSats

**Jerry Buxton, N0JY**
**Vice President, Engineering**

*1. Costs.* While the free launch — such as with our ELaNa-sponsored missions — saves around $100,000, our total costs are not exactly small, in amateur radio terms. Components and system assemblies average about $2500 per CubeSat. Environmental testing typically costs from $14,000 to $15,000 depending on the testing required. The huge amount of volunteer labor far exceeds even the launch cost, and none of our missions would be possible without our volunteers.

*2. Requirements.* From component makeup to mass, to center of gravity to dimensions within 0.2 mm, the CubeSat must conform to specific values and volumes for the operation of the rocket and the safety of the mission. The CubeSat must be able to survive strict environmental conditions, including vibration, shock, temperature and RFI. The launch provider requires specific environmental testing to show that you comply. No test? No fly. Fail a test? No fly, unless you fix it and retest it in time.

*3. Safety.* While the launch provider may have a passing interest in seeing our mission succeed, the provider requires that we simply pose no risk to their rocket, primary satellite, or any of the other CubeSats in the launch. We must comply with numerous and critical requirements to demonstrate that we will not pose a risk. We often have to explain, test, and justify certain design aspects, which may even include a redesign to meet the safety requirements. That is truly all that matters for the launch, in the end.

*4. Cleanliness.* The last environmental test performed is the thermal vacuum bakeout, which subjects the CubeSat to a high temperature in a vacuum for hours to bake away contaminants such as absorbed water, finger oils and residues from construction. If you don't bake, when the CubeSat hits the vacuum of space those nasty things will evaporate and often find a nice cool place to resettle. A camera lens could be one of those places, and you certainly don't want that. After bakeout is completed, the CubeSat is placed into an anti-static bag and sealed.

We must then maintain cleanliness up to the time of delivery and integration into the deployer.

5. *Imagers.* For U.S. missions, the government requires a license to operate your camera or imager. The license is obtained through NOAA, although NOAA is more of an agent for several government agencies who are interested in protecting critical U.S. assets from spying. That protection includes images of space as well as images of Earth.

Typically, you are required to encrypt the downlink of any images, and you cannot share or sell them without approval. For amateur radio satellites, the situation becomes trickier because the FCC does not allow encryption of amateur radio transmissions other than the command and control of the satellite. A lot of paperwork and demonstration of the ability to protect the satellite from unauthorized image-taking is required for any NOAA license, and the inability to encrypt the downlink compels other remedies to suit the licensors. In the case of Fox-1Cliff and Fox-1D, we are only allowed to take images of Earth's surface.

6. *Licenses.* While technically speaking we are not required to obtain an FCC license for our CubeSat, the launch provider is required to show the FAA that all of the RF emissions from the vehicle and payloads are licensed. The FCC requires a thorough notification of the design and intent to operate an amateur radio space station. That is in addition to us obtaining IARU coordination, which is also required by the launch provider. We are also required to show the FCC that the CubeSat will re-enter the atmosphere and burn up in less than 25 years to satisfy orbital debris mitigation.

7. *ODAR.* The Orbital Debris Assessment Report (ODAR) must be filed with the FCC paperwork. The FCC acts as an agent/repository, just as NOAA does for the imagers. ODAR is an extensive report that describes the makeup of the CubeSat down to the nuts and bolts. The report includes several descriptions and analysis (with NASA provided software) of the likelihood of any pieces of the CubeSat striking Earth's surface upon re-entry and breakup. If any pieces may survive the trip, depending on the energy of those pieces when they reach the surface, some major liability insurance might be required.

8. *Teamwork.* Teamwork goes beyond AMSAT and often extends to some or all of the other CubeSats flying on the same mission. Selection and manifest are based on desired orbits and available space, and CubeSats by design are somewhat flexible in the way that they can be integrated into the deployer. However, missions sometimes depend on specific partners and combinations of CubeSat sizes to be viable. If one team fails to deliver, others may be affected and unable to launch as well because of that "hole" in the manifest. Being one of the more experienced groups with satellites in general, AMSAT often helps other teams to overcome their challenges so that we can all fly happily, together.

9. *Launches.* While you may be familiar with launch delays on the order of a particular launch being delayed due to weather or an anomaly during the launch window, the schedule for launch is very fluid long before we are even manifested on that launch. The launch date will move, and seldom if never "to the left" (an earlier date). It may move many times during mission preparation, and often the move does not come soon enough to allow more preparation time. Ideally, our CubeSats would not be sitting in the NPSCUL as AO-85 was, or in Fox Labs as are Fox1Cliff, Fox-1D, and RadFxSat, for longer than a month. While many might be amazed or annoyed when a later launch date is announced for one of our CubeSats, internally we typically regard it is a slight disappointment and "yeah, OK."

10. *Murphy's Law.* Yes, this is amateur radio and, yes, Murphy is Amateur Radio Satellite's middle name. With a CubeSat, you can be sure that nothing will work right the first time, and everything won't work together quite the way it should. Something will be working and then just quit, and the reasons for any of that will be hard to discern. Sometimes your shipments will be delayed, or components will go end of life, or test facilities will lose key employees right when you need them.

Maybe the next very, very similar CubeSat you build will have a whole new set of issues of its own. While all of these ten things are big challenges, I think this one is the one that always puts even the most experienced CubeSat team at risk for delivery! ⊕

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# ARISS Update: ARISS International Delegates Meeting & 20th Anniversary Celebration

**Frank Bauer, KA3HDO**
**Vice President, Human Spaceflight, and**
**Rosalie White, K1STO**

## Humble Beginnings
*Tempus Fugit! Time Flies!*

It is hard to believe that it has been over 20 years since a U.S. team from AMSAT and ARRL met in Houston with other international amateur radio organizations and NASA to set up what is now the Amateur Radio on the International Space Station, or ARISS, program. In those heady days, the U.S. Shuttle Amateur Radio Experiment (SAREX) team was starting to wind down Space Shuttle operations because NASA was gearing up for long duration operations on the Space Station MIR with our Russian colleagues. Moreover, NASA would soon have no time for payload activities like SAREX because in two years NASA would totally focus the space shuttles and their crews on the construction of the International Space Station (ISS).

During the mid-1990's, several factions within the United States and internationally had very different and conflicting views on how to collaborate, develop, and operate an amateur radio station on the ISS. Some had on-orbit experience on the Space Shuttle and Space Station MIR. Because SAREX was sponsored by NASA education and had formal agreements in place with NASA's Human Spaceflight Directorate, the SAREX team was first to petition NASA for an opportunity to fly and operate equipment on ISS. A very wise Pam Mountjoy, from NASA Headquarters Education, challenged the international ham radio community by stating: "If you really want a permanent amateur radio station on ISS, you need to combine the efforts of all the amateur radio groups across the world. You need to have one voice to NASA in the development and operation of your ham radio systems. Only then will NASA agree to moving forward."

Pam saw the differing opinions and groups, and she wanted one voice into NASA with one interfacing ham team. She further challenged us to "Convene a meeting at NASA JSC with the international amateur

radio stakeholders attending to work out the formation of an international working group to develop and operate your systems on ISS." With these NASA challenges in-hand, AMSAT and the ARRL worked diligently to gather a contingent of partners from the U.S. and around the world to attend a formulation meeting in Houston and to wade through the differing opinions, diverse cultures, and sub-optimal radio rules and laws to develop a cohesive ham radio strategy for ISS.

On November 4-5 1996, a team of amateur radio operators from Canada, Europe, Japan, Russia and the U.S. met with NASA at the NASA Johnson Space Center in Houston, Texas and conducted the first international amateur radio meeting for the International Space Station. At the end of the meeting, the team created a new name for this NASA-sponsored working group: ARISS. NASA's response to what we accomplished: "We did not think you would be successful in making this happen, especially as quickly as you did." But we were successful. We made it happen! And the rest is ARISS history!

## ARISS International Face to Face Meeting and 20th Anniversary Celebration

To commemorate our 20th anniversary as a team, ARISS International met at the NASA Johnson Space Center November 15-18, 2016 to celebrate our past and formulate our future. The ARISS meeting date was set to start just after the completion of the AMSAT Symposium at Sea so that those interested could attend both events. Those who arrived in Houston early were treated to a VIP tour of the NASA Johnson Space Center on November 14th. This tour included training mockups of the Space Shuttle, Orion Crew Launch Vehicle (for deep space exploration), and the ISS FGB module. They also toured Mission Control, including the ISS flight control room and the Apollo control center, where, during Apollo 13, the astronauts radioed down "Houston we have a problem," and NASA flight controller Gene Kranz said the famous words, "Failure is not an Option." The tour group also visited NASA's Neutral Buoyancy Lab, the world's largest swimming pool where NASA trains its astronauts for spacewalks.

ARISS meeting activities kicked off on November 15. Over the next four days, we covered a multitude of topics. Unlike previous years, we conducted business with all team members present in plenary sessions that were usually conducted at the beginning and end of the day, and then split the team up into two parallel sessions that discussed three main topics: Hardware Development, Educational Outcomes and Sustainability and Funding. Some of the highlights from the meeting follow. Detailed meeting minutes will be available for review on the ARISS website, **www.ariss**.org, after approval by the ARISS delegates.

One of ARISS's primary benefactors is CASIS, the Center for the Advancement of Science in Space. CASIS Education lead Dan Barstow, KA1ARD, presented a talk during our first plenary entitled, "ARISS as part of CASIS Space Station Explorers: Launching Student and Public Interest and Education in ISS, Amateur Radio and Space Exploration." His talk included very inspiring pictures and videos from ISS. He reported that ARISS led the way as the first ISS program with active participation from people on the ground. He applauded our work and stated that ARISS is "way up there" compared to other programs in its reach to people worldwide.

## Hardware Development

We made excellent progress on the Interoperable Radio System at this meeting. A key effort completed was the finalization of the operations firmware and software that will be embedded in the JVC Kenwood TM-D710GA radio systems. The embedded firmware and software will include settings, APRS features, PM modes and frequencies. We were fortunate enough to have JVC Kenwood experts attend our meeting and support the finalization of the JVC Kenwood D710GA design for ISS. JVC Kenwood team members included ARISS D710 Project Chief Designer Shin Aota, JL1IBD, and U.S. Sales Manager Phil Parton, N4DRO. In addition, APRS inventor, Bob Bruninga, WB4APR, participated in the D710 firmware and software finalization.

By the end of the week, a set of firmware and software was delivered to the ARISS team for incorporation in all D-710GA units to be flown and operated on ISS, as well as training and ground test units. ARISS remains deeply indebted to JVC Kenwood for its donation of equipment and engineering expertise to make the interoperable radio system an outstanding amateur radio communication tool for astronauts on-board ISS and hams and schools on the ground.

Before the ARISS-I meeting, Kerry Banke, N6IZW, completed a breadboard version of the multi-voltage power supply. He also developed load simulators and voltage sources to test the system end-to-end. During the meeting, the power supply and simulators were integrated with the D710GA to demonstrate the interoperable system, allow NASA experts to view the system and ask questions, and work through design and development questions and issues.

Ciaran Morgan, M0XTD, discussed opportunities to repurpose the Tim Peake Astro-Pi, a modified Raspberry-Pi that was certified for use in space and was employed by students who wrote programs for the Pi as part Tim Peake's Principia STEM outreach activity. Ciaran shared with ARISS hardware proposal ideas, related educational opportunities, and potential strategic benefits of having ARISS partner with the Raspberry-Pi Foundation. The Raspberry-Pi Foundation provided ARISS with a long-term loan of four ARISS-Pi units. ARISS-Pi is a proposal to be considered by the team whereby ARISS would ask to use the Astro Pi equipment and get partial or full flight certification for it. ARISS thanks the Raspberry-Pi Foundation for its interest in ARISS.

A special plenary session was held with representatives from Global Receive Antenna and Signal Processor (GRASP). The objective of GRASP is to use the ISS to help collect terrestrial RF data. GRASP plans to replace the AIS antenna on the ISS Columbus module. As AIS and ARISS share a common ISS feedthrough, this would mean that ARISS needs to work with GRASP and replace our antenna on Columbus with the GRASP hardware delivery. Planning is on-going.

## Sustainability and Funding

Frank Bauer, KA3HDO, gave several presentations on ARISS strategic planning, starting with a presentation on the ARISS-U.S. team's recently developed strategic plan and budget. He reviewed ARRL's strategic plan, gave some strategic planning-101 presentations and then worked with the international team in a brainstorming session to gather information critical to formulating an ARISS international strategic plan.

## Educational Outcomes

The Educational Outcome team conducted three sessions and some plenary discussions detailing activities and ideas that are expected to improve the educational impact of ARISS. Team members in Russia,

Japan, Canada, Europe and the U.S. all had materials and presentations to share. Debra Johnson, K1DMJ, from the ARRL, shared results of a survey she conducted on the impact of ARISS as viewed by the local hams and club members who volunteered at ARISS schools.

Austin Texas educator Ronny Risinger, KC5EES, described classroom activities he conducted for an ARISS contact. Francesco DePaolis, IK0WGF, presented education plans for upcoming missions with Astronauts Paolo Nespoli, IZ0JPA and Thomas Pesquet, KG5FYG. He also reviewed the new school group selection process that ARISS-Europe has implemented. Sergey Samburov, RV3DR, and Tatiana Kolmykova spoke about student activities as part of the Gagarin from Space program and provided more detailed information on several CubeSats to be deployed from ISS mid-2017, including the Tomsk University CubeSat.

## Astronaut and Cosmonaut Visits

The ARISS team was blessed with visits from one Russian cosmonaut and two U.S. astronauts. Astronaut Mike Fincke, KE5AIT, attended the meeting and spoke very highly of ARISS and how much he had enjoyed talking to young students during ARISS contacts. Frank Bauer, KA3HDO, presented him with an ARISS Challenge Coin for his phenomenal support to ARISS.

Cosmonaut Aleksandr Poleshchuk, RV3DP, also visited and recounted a story about the first amateur radio contact between an astronaut in the space shuttle and a cosmonaut (himself) on Mir. As the head of EVA activities for Roscosmos, Poleshcuk was a key advocate and was instrumental in the final approval of the ARISS SuitSat and ARISSat missions. Astronaut Ken Cameron, KB5AWP, who supported several SAREX missions, also attended the ARISS meeting and honored the group by coming to the 20th-anniversary commemorative dinner.

## Texas BBQ

A great time was had by all at Kenneth and Beth Ransom's house as they hosted a wonderful Texas BBQ on Tuesday, November 15. As the photos illustrate, the ARISS team mingled and enjoyed each other's friendship while savoring the mouth-watering food provided by our hosts. Kudos to Beth and Kenneth for opening up their home and providing a memorable dinner for all.

## 20th Anniversary Celebration Dinner

The 20th-anniversary dinner was held on Wednesday, November 16, 2016, at Red, which is part of the Landry's group of restaurants located at the Kemah Boardwalk in Kemah, Texas. As people arrived, they were entertained with a special slide show spanning the 20 years of the ARISS program. The slide show included team member photos, meeting and event activities, hardware developments, ISS crew members, memorable school contacts, etc.

Following the scrumptious dinner, Frank Bauer, KA3HDO, gave a multimedia presentation looking back 20 years, including video clips from our first meeting in Houston. It was fun to see how we have changed (and matured) since 1996! Astronaut Ken Cameron, KB5AWP, attended our celebration and shared his experiences as an astronaut using ham radio in space. He concluded by congratulating the ARISS team on their 20th anniversary.

Frank Bauer, KA3HDO, Rosalie White, K1STO, and Debra Johnson, K1DMJ, presented beautiful custom-designed certificates, courtesy of the ARRL, to ARISS volunteers supporting ARISS for 10 years, 15 years, 20 years of service, and to the ARISS Founders. Joe Spier, K6WAO, led a toast to the ARISS team for a phenomenal 20 years. All in all, we had a great time commemorating the awesome efforts that our international team has accomplished in the past 20 years.

## In Closing

Looking back, it is breathtaking to see how much our team of ham radio operators has done in 20 years. We were the first operational payload on ISS. We were the first group outside a space agency to allow the general public to talk to astronauts on ISS, and the first non-space agency to downlink video from the ISS. Astronauts on ISS have called our signals "the cleanest audio they have heard on ISS." We have jump-started students' careers, touched millions from all walks of life and, in some cases, become a local or international phenomenon.

Poor, disadvantaged students and heads of states have participated in our contacts. We have been storylined in the National Geographic Mars Prequel, included as part of the IMAX Space Station 3D Film, and were part of numerous television shows, including the History Channel's Ice Pilots series. We have participated in the search for Amelia Earhart's plane, and we were the first to realize a science fiction movie vision with the deployment of SuitSat-1. This is the tip of the iceberg of what this team has accomplished in twenty years. Can you imagine what we will accomplish in the next twenty?



Frank Bauer, KA3HDO, ARISS International Chair, welcomes and congratulates team members on their 20th anniversary. [Photos courtesy of Frank Bauer unless otherwise noted.]
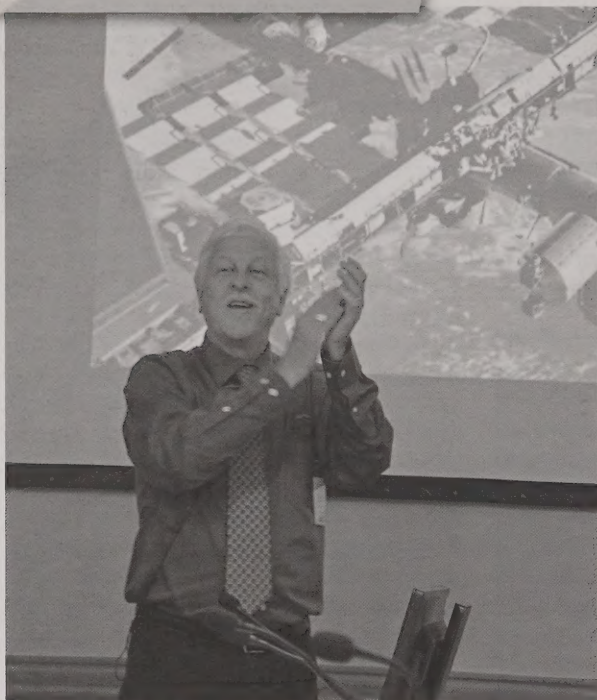
Dan Barstow, KA1ARD, from CASIS congratulates the ARISS team on a fantastic 20 year effort. [Joe Spier, photo.]



Debra Johnson, ARISS-US, ARRL, presenting "ARISS Education in the USA"



Sergey Samburov, RV3DR, and Tatiana Kolmykova present ARISS Educational Opportunities in Russia.
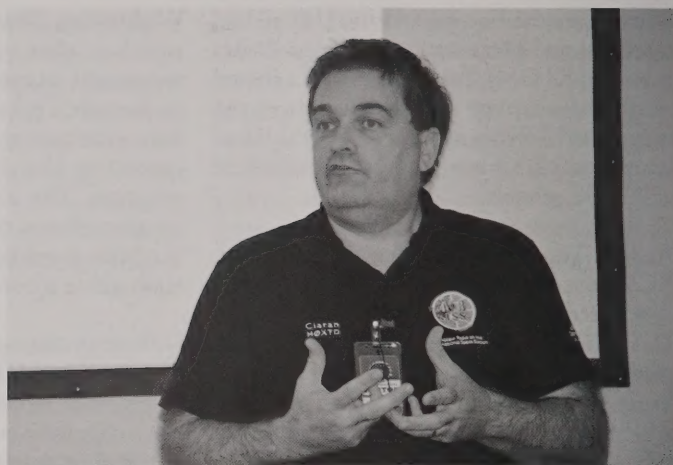


Ciaran Morgan, M0XTD, presents "ARISS Astro-Pi Opportunity." [Joe Spier, photo.]
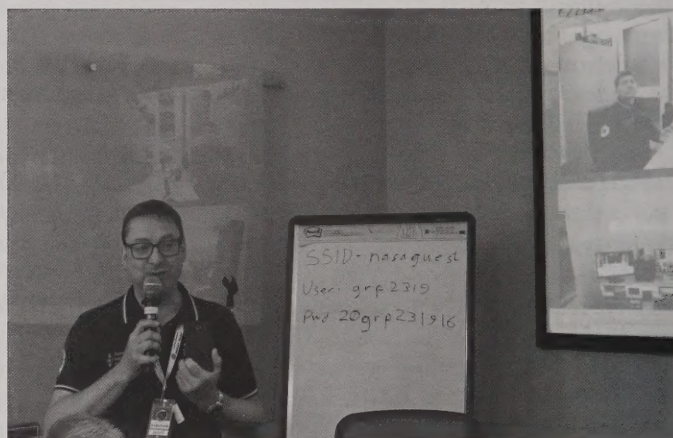


Claudio Ariotti, IK1SLD, livestreams with the Telebridge Station at Casale Monferrato, Italy.
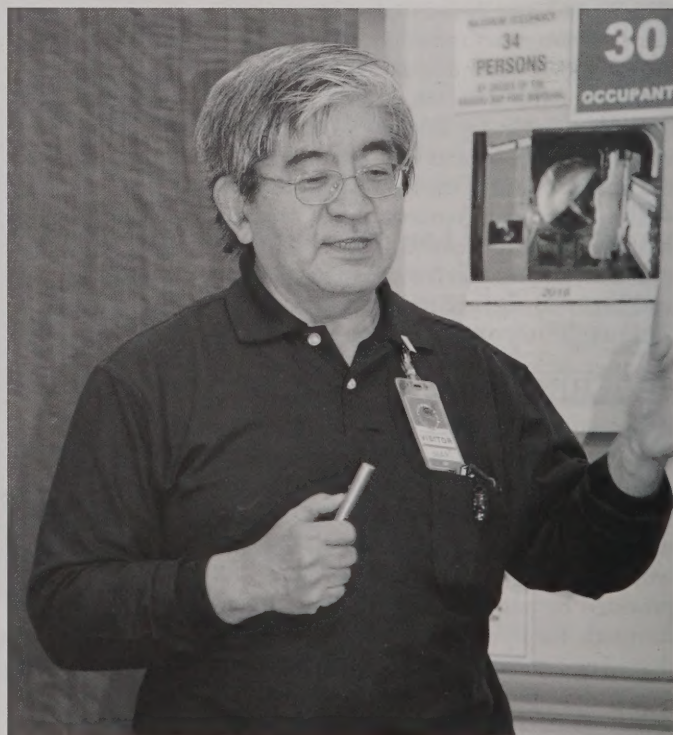


Satoshi Yasuda, 7M3TJZ, presents "ARISS Education in Japan." [Joe Spier, photo.]

(L to R) Beth Ransom, Kenneth Ransom, N5VHO, and Francesco De Paolis, IK0WGF, at Ransom BBQ.
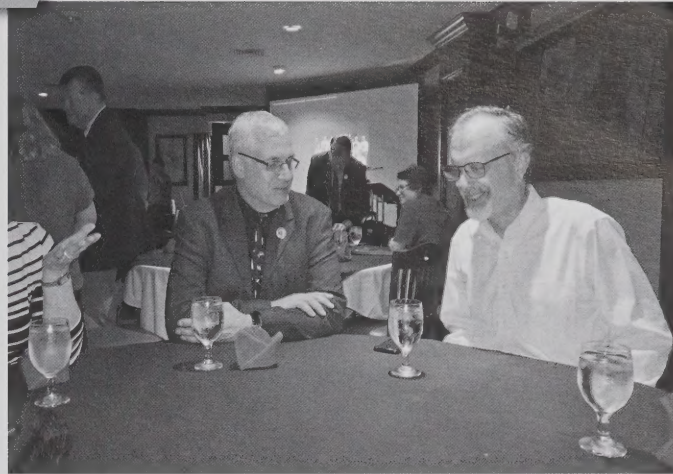


Oliver Amend, DG6BCE, and Phil Parton, N4DRO enjoying a pre-dinner discussion. [Ciaran Morgan, photo.]



(L to R) Rosalie White, K1STO, Dave Taylor, W8AAS, Frank Bauer, KA3HDO.



(L to R) Rosalie White, K1STO, Lou McFadin, W5DID, Frank Bauer, KA3HDO.



(L to R) Rosalie, Bob Bruninga, WB4APR, and Frank.



(L to R) Rosalie, Francesco De Paolis, IK0WGF, and Frank.
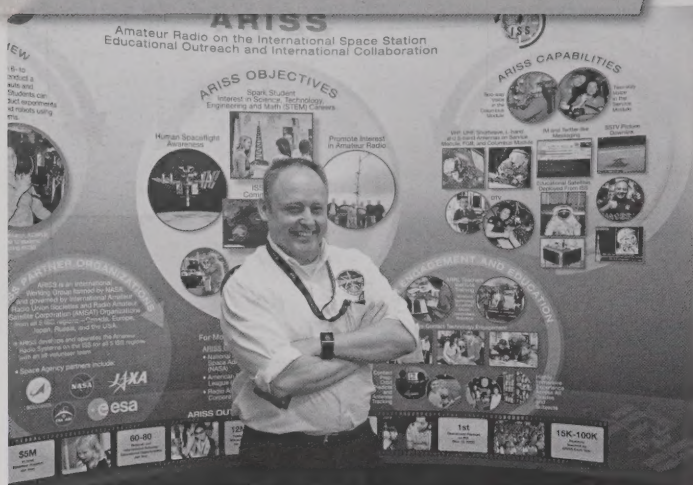
Astronaut Mike Fincke, KE5AIT in front of ARISS display.



Cosmonaut Aleksandr Poleshchuk, RV3DP — instrumental in the approval, development and deployment of SuitSat-1 and ARISSat-1. [Ciaran Morgan, photo.]
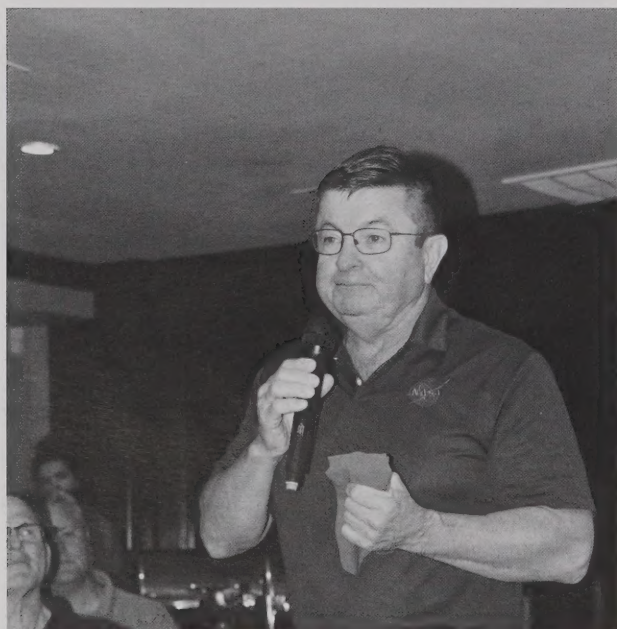


Ken Cameron, KB5AWP, shares his experiences as an astronaut using ham radio in space and congratulating the ARISS team on their 20th anniversary.



Matthew Bordelon, KC5BTL, NASA JSC, ISS Avionics and Software Office.
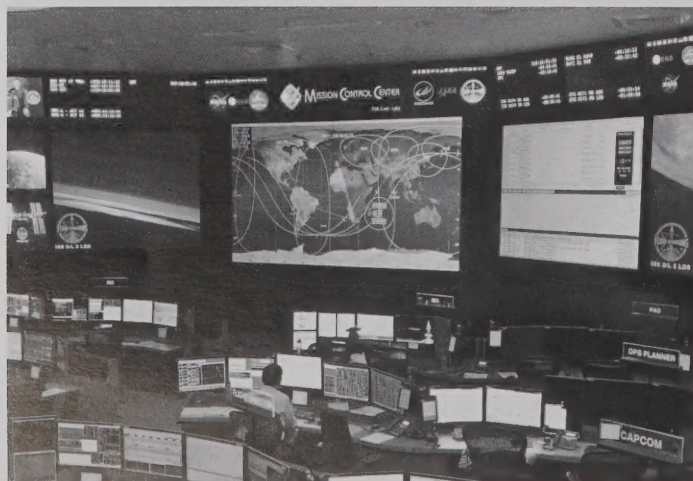


Mission Control. [Ciaran Morgan, photo.]



Group shot in Apollo Mission control room. [Ciaran Morgan, photo.]

Shin Aota, JL1IBD, and Bob Bruninga, WB4APR, discuss APRS operations with ISS on the JVC Kenwood TH-D74. [Ciaran Morgan, photo.]



Multivoltage power supply Breadboard. [Dave Jordan, photo.]



ARISS configured Kenwood D-710GA. [Dave Jordan, photo.]
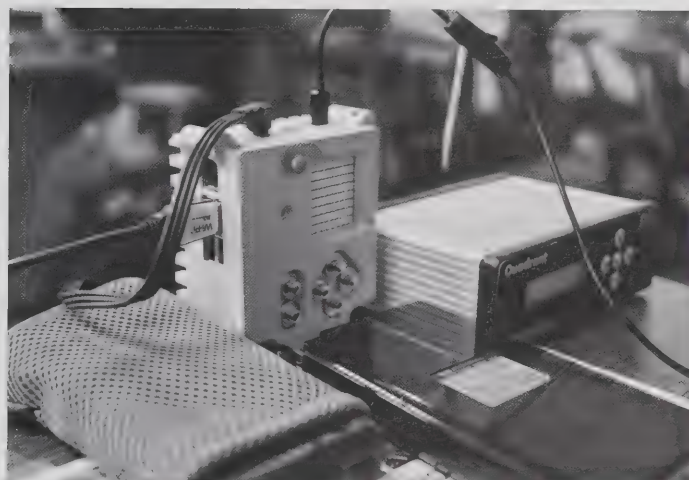


Astro-PI Prototype.
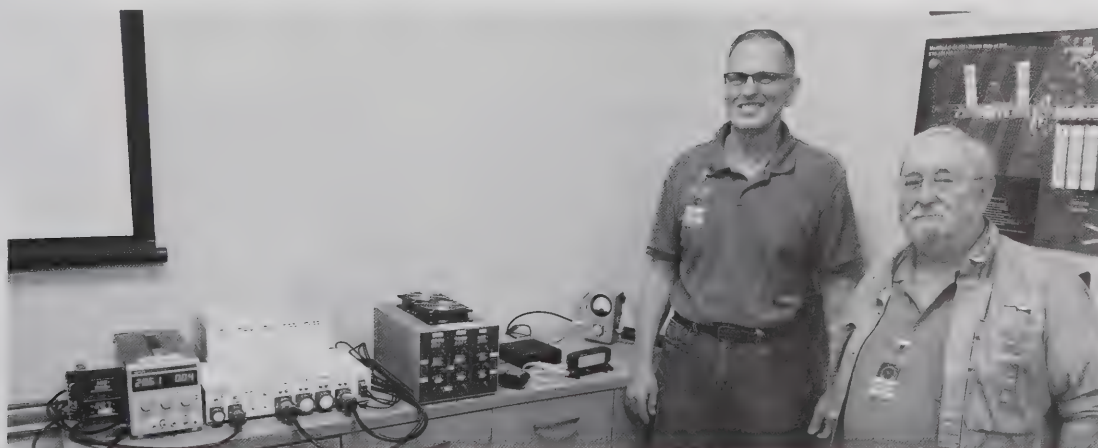


Lou McFadin, W5DID, and Kerry Banke, N6IZW, with Interoperable radio system test set up, including (from right to left) the JVC Kenwood D-710GA, the power supply load simulator, the Bread board multivoltage power supply and the 28 VDC simulated voltage source. [Dave Jordan, photo.]

# Get On the Air with ARISS Packet

**JoAnne Maenpaa, K9JKM**
**k9jkm@amsat.org**

The Amateur Radio station aboard the International Space Station (ISS) is known as ARISS — the Amateur Radio on the International Space Station. Many astronauts and cosmonauts have Amateur Radio licenses. Amateurs from the ISS partner countries in the U.S., Russia, Japan, Europe and Canada, have set up the ARISS program to foster Amateur Radio communications between the astronauts and cosmonauts who reside on the station and stations on the ground.

ARISS gained access to the IS S to help NASA fulfill Science, Technology, Engineering, and Math (STEM) goals for education. ARISS is an international educational outreach program partnering the participating space agencies — NASA, Russian Space Agency, ESA, CNES, JAXA, and CSA — with the AMSAT, ARRL, and IARU organizations from participating countries.

ARISS offers an opportunity for students to experience the excitement of Amateur Radio by talking directly with crewmembers onboard the ISS. Teachers, parents and communities see, first hand, how Amateur Radio and crewmembers on the ISS can energize youngsters' interest in science, technology, and learning.

In between support of STEM activities, the ARISS Amateur Radio gear offer a side benefit of being available to the Amateur Radio community at large. Often, tight crew schedule timelines prevent the astronauts from engaging in general voice contacts with Amateur Radio operators on Earth, but the ISS packet station remains operational.

Additionally, if one of the ground based Internet Gateway (IGATE) stations receives your broadcast, then it will be posted on the ARISS.net web page. The way it works is volunteer operators around the world host ground stations connected to the Internet through APRS client software that includes an IGATE feature. Digipeated stations and their positions "heard" by the APRS ground station are fed via the IGATE to Internet maps.

To see a log of stations all over the world digipeating through the ISS (including your own packets), go to **ariss.net**. The list at ariss.net has several hours worth of stations logged. If your AX.25 UI formatted message contained an APRS position report, your station would be displayed on the map (Figures 1 and 2). Also available is a chronological list of stations and messages captured by the IGATE stations.

## 2 Meter and 70 cm Band Uplink and Downlink

Until recently, packet radio activity from the ISS on the 145.825 MHz downlink originated from the ARISS Ericsson two-meter HT. When this 2-meter radio failed, it was replaced with an identical Ericcson 70cm HT operating on 437.550 MHz.

In this mode, the uplink and downlink frequencies are the same. The packet digipeater uses the uplink/downlink on the same 145.825 MHz or 437.550 MHz frequency. The current packet configuration uses the 437.550 MHz frequency.

Since the crew rarely engages in keyboard contacts, most of the packet activity you are hearing is originated from Earth stations using the ARISS digipeater. Lacking packet gear, you will only hear the brzzzzz-brap sound of the 1200 baud audio frequency shift keyed (AFSK) signal.

## Getting on the Air with Packet

Getting on the air with the ARISS packet digipeater can likely be accomplished with Amateur Radio gear you already own. No special Amateur Radio equipment beyond what is used for terrestrial packet contacts is needed to begin taking your first steps toward Amateur Radio packet operating in space. This means if you do not own certain items they can likely be acquired
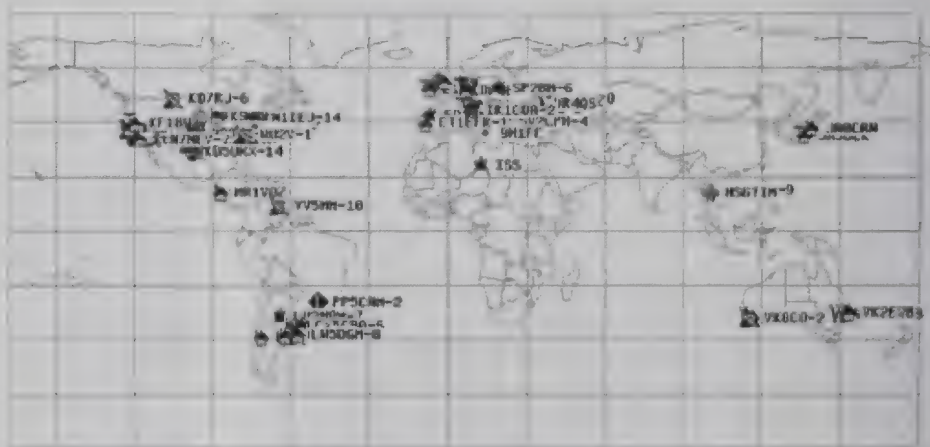


Figure 1 — Ariss.net shows a map of stations digipeated via the ISS on 145.825 or 437.550 MHz.
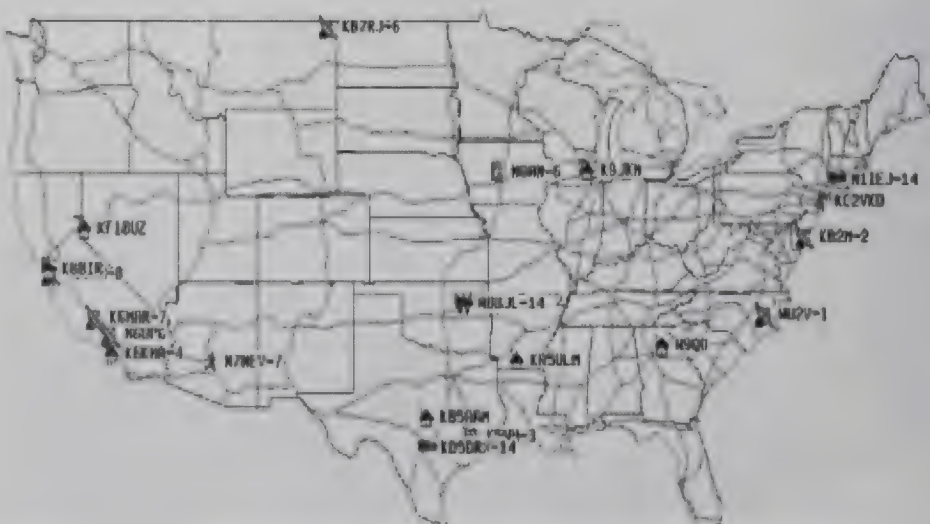


Figure 2 — Selected portions of the Earth can be viewed in detail since the global map is "zoomable" along the lines of using online Google Maps.

inexpensively. Think of ARISS packet radio as regular terrestrial ham radio packet aimed skyward.

Additional good news is that once you have equipped your station for ARISS packet and learned the ropes for ARISS packet operation, your station will be ready for those rare voice contacts with the ISS crew. You will just need to switch the packet gear for a microphone and start calling.

## Ground Station Requirements

For your packet ground station, a standard 2-meter 70cm, or dual-band FM transceiver with 5 to 30 W into a Yagi antenna that can be pointed in both azimuth and elevation provides the best performance. Several stations report moderate success with externally mounted vertical antennas so don't let the availability of a Yagi prevent your packet operation via the ISS.

The downlink signal from the ISS is generally easily heard but you will not have much luck trying to get your packets through the digipeater with an indoor antenna or with the flexible antenna on your HT.

The good news is that your external antenna does not require full OSCAR-class tracking and control. Many enjoy success with a VHF vertical antenna on the roof of the house. A small beam need not be complex. A 3-element VHF beam at a fixed elevation of 15-20 degrees on a small TV rotor provides a good start.

## Doppler Shift

Doppler shift on 145.825 MHz is minimal enough that most 2-meter radios will not require frequency tracking during an ISS pass. However, on 437.550 MHz the Doppler shift is +/- 10 kHz during an ISS pass. This needs tracking for success (Figure 3).

Operators can choose between three approaches to encode/ transmit and receive/ decode the 1200 baud AX.25 AFSK packet messages:

- Use a Hardware Terminal Node Controller
- Use a software-based computer soundcard Terminal Node Controller, or
- Use an APRS capable HT such as the Kenwood TH-D74A or TH-D72A. [This article focuses on the hardware and software TNC approaches; see the separate article in this issue about using the Kenwood TH-D72A and TH-D74A.]

```
**************************************
* 70cm ISS packet on 437.550 MHz  *
*         (+/- for Doppler)        *
*                                  *
* Channel    Receive    Transmit   *
*    1       437.560    437.540    *
*    2       437.555    437.545    *
*    3       437.550    437.550    *
*    4       437.545    437.555    *
*    5       437.540    437.560    *
**************************************
```

Figure 3 — Example of Doppler-shifted UHF ARISS frequencies. [Courtesy of Patrick Stoddard, WD9EWK.]

## Use a Hardware TNC

When packet radio was a popular terrestrial operating mode on VHF/UHF many years ago, you may have acquired your Terminal Node Controller (TNC) which you interfaced to your computer and FM radio (Figure 4). You may have a TNC sitting on the shelf collecting dust. This same "old" hardware, capable of operating terrestrial

1200 baud AX.25 AFSK modulation is still useful for packet radio operation via the ISS.

There were many models of the AX.25 TNC including the MFJ-1270C TNC-2 Packet Controller and the Kantronics KPC-3 TNC.

If you don't have a TNC that you used in the "old days," one can often be purchased rather inexpensively at a hamfest. When you see a good deal, grab it if you prefer the hardware approach to packet operation.

## Use Your Computer and Software

In the years since the peak of the hardware TNC based activity, software for sending and receiving an AFSK packet signal has been created for the sound card in your personal computer. Your computer with a soundcard interface and packet software will perform the functions previously provided by a TNC hardware box (Figure 5).

In addition to the soundcard software you
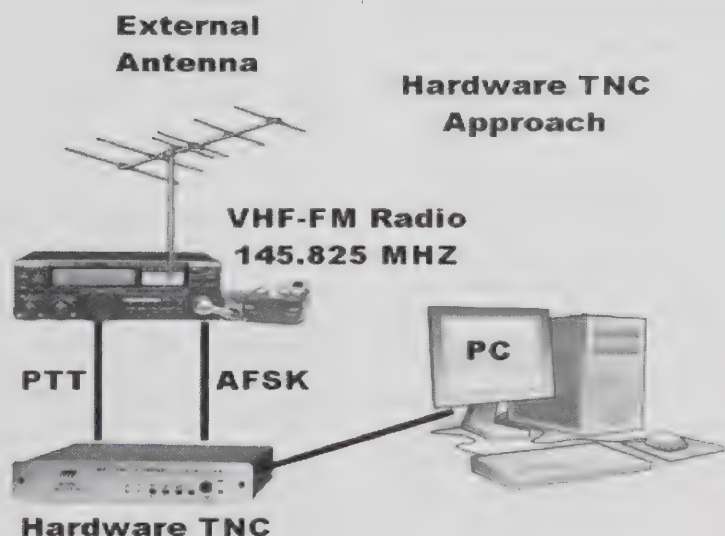


Figure 4 — Basic configuration of a hardware-based packet system.
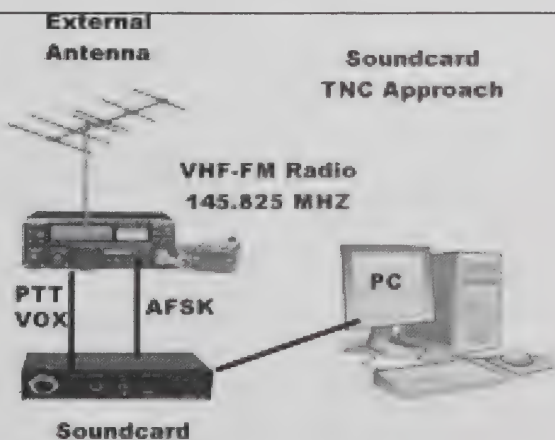


Figure 5 — Basic configuration of a soundcard-based packet system.

will need to install a soundcard interface between your radio and your computer to adapt the signal levels to be compatible with the digital signal processing done by the soundcard. You have a few options to this approach also:

- Build a soundcard interface from plans found on the internet
- Rigblaster by West Mountain Radio $100-$300 (www.westmountainradio. com), or
- Donner Digital Interfaces $40-$100) (**www.k8be.net/donners_ country_ crafts_and_digital_interfaces. html**)

Whether you choose the hardware TNC or the software/soundcard TNC approach depends on what gear you have on-hand. (One added bonus of using a soundcard interface is that you will be able to copy the slow scan TV events from the ISS by simply starting SSTV software instead of the packet software.)

## Overview of Operating Through ISS Using the Hardware TNC

Much of terrestrial packet operation consists of you requesting a CONNECTION to another station. Packet communication via ISS almost exclusively relies on using CONNECTIONLESS operation.

The AX.25 protocol defines these types of packets as UI packets. An UI packet is pretty much transmitted out there for anyone and everyone to receive and copy. When stations transmit UI packets, the AX.25 protocol will not be waiting for all of the handshake messages to complete. This greatly simplifies the message exchanges. A few parameters in the TNC make UI operation an easy mode to operate.

Every AX.25 packet that you transmit consists of two main parts: The Packet Header & Message Text. The Header contains your callsign which you set with the MYCALL command. Other packet stations will "know" it is a UI packet - a packet for everyone - based upon what you set using the UNPROTO command.

The most basic, barebones UNPROTO needed for ISS packet is simply set UNPROTO CQ VIA ARISS. Additional strings used for terrestrial packet such as WIDE, WIDE1-1, etc., do nothing for packets routed via space. This additional formatting is ignored. It also adds overhead to your transmitted packet making it more error-prone in congested operation (such as when dozens of stations are attempting to digipeat via the ISS).

Assuming I have my route defined as UNPROTO CQ VIA ARISS (or, UNPROTO CQ VIA RS0ISS), now all I need to do to transmit an UI packet from my station is to enter a short text message via the keyboard and terminal program on the PC. This requires the use of the TNC's CONVERS command as outlined here:

- Set UNPROTO CQ VIA ARISS;
- Enter CONVERS mode from the cmd: prompt on your TNC screen;
- Enter a short message such as Greetings from JoAnne via the space station and hit <enter>; and
- You should see your TNC key your rig and send the message.

While you are in CONVERS mode all input from your keyboard is transmitted every time you hit the <enter> key. To exit the CONVERS mode at the end of a pass use Control-C (usually) to get back to the TNC cmd: prompt.

When the TNC-2 hardware is in a connection with a specific station node or in the CONVERSE mode it generally does not display all packets. Refer to the TNC command summary table for details, but setting MONITOR ON, MALL ON, MCON ON will allow you to see all of what is going on the channel. Refer to the TNC-2 command table for details.

The actual keyboard syntax to enter the commands into your TNC (from the cmd: prompt) will likely vary according to the manufacturer. Refer to the table below for a TNC command summary.

## APRS Format Location Information?

ARISS status displayed at **www.ariss. net/** includes an APRS map showing station locations.

You do not need to run any extra APRS software to be displayed on the map. You can generate the APRS format directly at your keyboard if you wish to show up on the map. If you wish to simply send text messages to be digipeated via the spacecraft you simply type your message without the location data. While your QTH isn't showing on the map your packets will in fact still be digipeated – and you will see that on your screen.

Where do you find your APRS location information? This is just your GPS location. If you do not have access to a GPS box simply find your QTH on Google Earth (in the View -> Grid menu).

So if I would like to display K9JKM on the map using my latitude and longitude plus send a message to my fellow space-packeteers, I should send a text string using

| Summary of the TNC commands | | |
|---|---|---|
| TNC Parameter | Value | Description or Action |
| MYCALL | Your Callsign | Default is NOCALL, but you want others to know you are there. |
| DAYTIME | YYMMDD+HHMM | Used if you want to timestamp the packets you are receiving. |
| MONITOR | ON | Displays all packets on the frequency |
| MALL | ON | Displays all packets on the frequency (connected or unconnected) |
| MCOM | ON | Displays the AX.25 protocol with the message |
| MCON | ON | Allow you to see all packets even when in CONVERS mode |
| MSTAMP | ON | Monitored packets are timestamped |
| MRPT | ON | Displays the entire digipeat path for the packets. |
| CONSTAMP | ON | Connect and disconnect status messages are timestamped |
| HEADERLN | ON | Header information is displayed on separate line from message text |
| PASSALL | ON | TNC will accept and display packets that have errors (noise) |
| PASSALL | OFF | TNC will only accept and display packets that have complete CRC. |
| CONVERS | <enter> | Starts UI communication mode. Sends packet message from keyboard directly to the TNC |
| MHEARD | <enter> | Displays your TNC's "heard" list (updated only when PASSALL OFF) |
| UNPROTO | CQ VIA ARISS | Most basic string for ARISS to copy, route, and digipeat your packet. Also used with NO-84. |
| UNPROTO | CQ VIA RS0ISS | Most basic string for ARISS to copy, route, and digipeat your packet specifically via the ISS |
| UNPROTO | CQ VIA PCSAT-1 | Basic string for PCSAT-1 for Sunlit ONLY operation. |

the UNPROTO and CONVERS steps previously outlined, and make my text message look like: =4211.29N/08827.08W-Greetings
<enter>

The parts of this message string can be explained as follows.

• =4211.29N/08827.08W is simply the = character plus my QTH info from Google Earth.

• The – is the 'dash' or hyphen. It tells the map to display me as the little house with antenna icon. The ARISS packet page above has a link where you can find other icons to represent you on the map

• Greetings <enter> can be any message text you wish. You will likely have better luck getting through and being digipeated if you transmit short messages.

• If I see someone on the downlink who I would like to have a keyboard QSO with, all I would need to do simply enter the message from the keyboard without any APRS-formatted location: "Hi Bob, good to see you this pass" will just send Bob (and everyone reading the packet mail) your message.

The www.ariss.net/ web page also shows a packet log of stations that have successfully digipeated. In this packet log the callsign with the asterisk (*) is last station to digipeat my packet. When you see RS0ISS* this shows that you were digipeated via the ISS!

Operating packet without the traditional standalone TNC requires a combination of software and hardware connections.

• Software will generate and decode the AX.25 packet signal using the digital signal processing capabilities of the soundcard in your computer.

• A soundcard interface box is needed to set the proper sound levels between the computer and the radio.

• Push-to-talk (PTT) rig control is often generated by the software by setting selected pin(s) of the RS-232 serial interface. Some radios such as a Yaesu FT-857D will reliably switch between TX and RX function if the VOX levels are set in the radio's operating menus.

• If you already have interfaced your

## Overview of Operating the ISS Digipeater Using Your Computer's Soundcard and Software
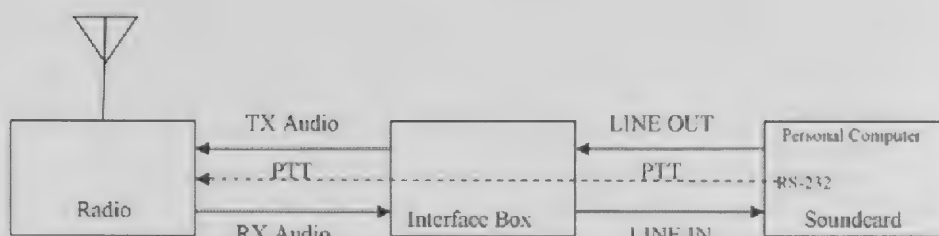


radio to the soundcard for other Amateur Radio applications such as RTTY, PSK31, JT65, and SSTV, you are already set for AX.25 ARISS packet operation with the ISS. All you need is to download, install, and configure some free software.

Since the connections between your radio and the soundcard interface of your choice are specific to your situation, we will defer discussion of this because you need to consult your radio operator's manual and the instruction book of the soundcard interface. Careful research before buying an interface box will reveal that many of the leading brands will also sell you an interface cable kit specific to your radio.

### Setting Your Soundcard Levels

If you are already using your soundcard for other Amateur Radio applications such as PSK31, etc., usually the same settings can be used for packet. If needed, use the "Wave" slider control to set the transmit level; use the "Line In" slide control to set the receive level (Figure 6).

### Install the Software You Need

The software you need for ARISS packet

operation is available for free download. The items you will need include:

• AGWPE — Written by George Rossopoulos, SV2AGW, it is an acronym for "SV2AGW's Packet Engine." It was originally created as a TNC management utility and has many features of value to TNC users, plus it has the ability to encode and decode packet tones using your computer's soundcard. Download from: **www. sv2agw.com/**.

• UISS — Guy Roels, ON6MU, designed it for UI packet communication (unproto) packet with ISS. This will be your user interface for packet communications with the ISS. This software is free for amateur and non-commercial use. A PRO version is available, and donations are welcome. Download from: **users.belgacom. net/hamradio/uiss.htm**.

Installation and user guides for the software packages are included on their websites. Here are a few links to websites that will give you the information needed to get on the air quickly:
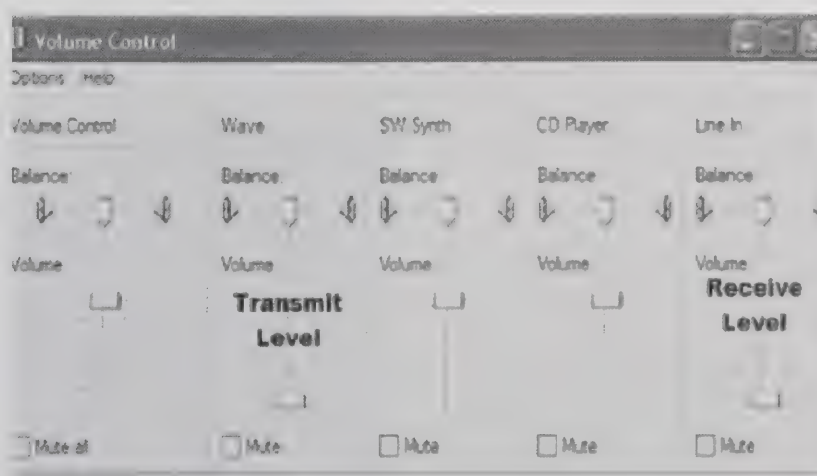


Figure 6 — The computer's sound controls are used to adjust the transmit and receive audio levels.

• The "golden" reference for soundcard packet configuration and operation is the "Sound Card Packet" site by Ralph Milnes, NM5RM: **www. soundcardpacket.org/.**

• Additional help for installing AGWPE is provided in a word document, "An Easy Set Up For Soundcard Packet," by Karl Berger, W4KRL. These are basic instructions for getting started, but you will not need the WinPack steps outlined. (We're using UISS instead.) **www. w4ovh.net/ SoundcardPacketSetup.doc.**

• Mineo Wakita, JE9PEL, has published several online references for the installation and use of UISS: **www. ne.jp/asahi/hamradio/je9pel/ ui32uiss.htm** and UISS setting up APRS satellite: **www.ne.jp/asahi/ hamradio/je9pel/uissagwp.htm.**

• The UISS site has a reference page: **users.belgacom.net/hamradio/ uisslinks.htm.**

## Example Operating Session With the Soundcard

Here is an example of an operating session to further acquaint you with this mode of operating.

(1) Always start AGWPE first (Figure7). Click on the AGWPE icon on your desktop and you will see the following splash screen telling you things are running. The splash screen will go away in about 10 seconds. You will also see the AGWPE Packet Engine startup "bubble" appear in the toolbar. You can "X" (to exit) the bubble but AGWPE will continue to run as shown by its icon in the toolbar. You can left or right click on the icon to get to AGWPE configuration settings if you ever need them.

(2) Start UISS (Figure 8). Click on the UISS icon on your desktop and the program will open to the operator screen.

• Your UNPROTO string CQ VIAARISS is set by using the pulldown menus in the To and Via windows in the top/left of the screen.

• The APRS-formatted location information which was also used in the hardware TNC configuration is entered in the TX Text/Data window.

• The MHEARD command used with the hardware TNC to show who is on the frequency has its equivalent display shown in the MHEARD list on the right side of the screen.

• To transmit my packet configured for digipeating via ARISS =4211.29N/08827.08W- I just click on the Text/Data button in the top row.

• UISS will show all of the packets being received when the ISS is within range. Your packet will be highlighted when you (and everyone else in range) receives the digipeated packet.

(3) Alternatively, you can display the stations you receive on an APRS-format map. In the example here, UI-View shows the stations received that were transmitting their location data during a pass of the ISS over the eastern half of North America. Start AGWPE first, then start UI-View (Figure 9).

## Using a Packet "Hard-Connect" to RS0ISS-11 BBS

In a word, please don't! The ISS PBBS with the ID RS0ISS-11 operates in the same manner as a terrestrial Packet BBS operates.



Figure 7 — Opening screen of the AGW Packet Engine (AGWPE). Once the program is initialized, it will become a icon in the system tools tray.



Figure 8 — UISS screenshot.

A "hard-connection" (C RS0ISS-11) establishes a full AX.25 connection which brings the entire messaging handshaking protocol into operation. The handshake messages will faithfully repeat, and repeat, and repeat all error messages, per protocol, until they are properly acknowledged.

The usual case is that many stations are sending packets to the ISS resulting in data collisions when RS0ISS-11 is expecting its handshake. Everyone tuned into the pass will see the endlessly repeating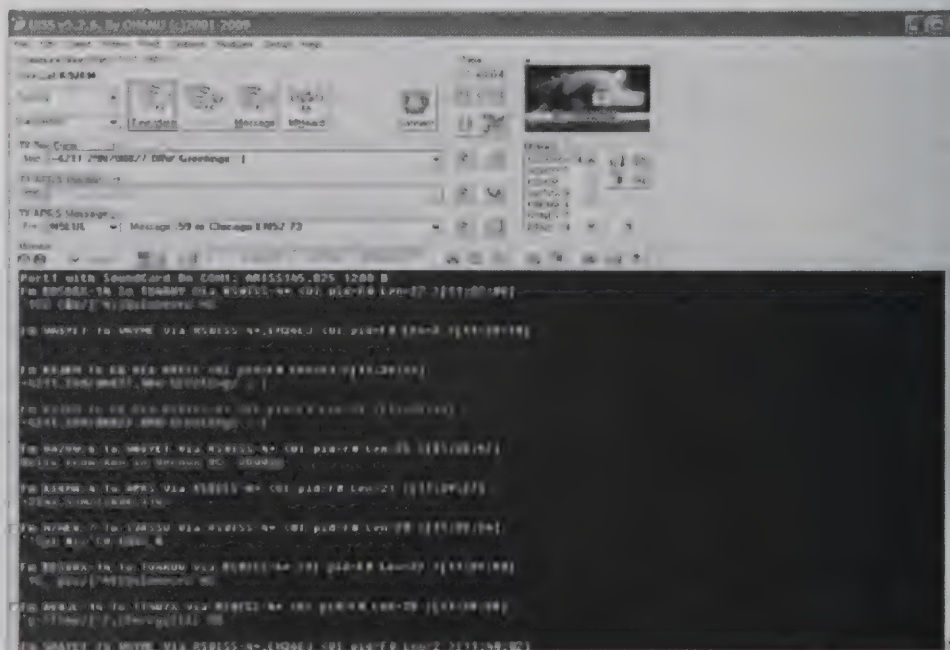 AX.25 handshake bytes until the sequence times out. You may have been out of range for several minutes already but the ISS is still listening for you. Although the PBBS is still configured there are NO useful files or messages. The ISS crew does not access these messages either. So, all of the greetings to crew have successfully tied up the channel but have failed to be delivered to the intended recipients.

## Swapping the UZ7HO Soundmodem Packet Program in Place of AGWPP

Many operators note that often a strong sounding downlink is heard from the ISS but the AGWPE and UISS combination of software will not decode and display the packet message. This is because the checksum was not correct. Losing only a bit or two of the digital packet due to noise or fading will result in that packet's checksum not being correct. AGWPE only passes the received packets that have a correct checksum. When using a hardware TNC with the PASSALL command enabled, you can see all packets, including the incomplete packets, or with reception errors. Often the packets with errors contain enough useful data for a human to still understand them. However, in the software TNC emulation, this command is not available.

I have read of other operator's experiences having better error condition response using the UZ7HO Soundmodem software in place of the AGWPE packet engine. Conveniently, the UZ7HO Soundmodem software, an AX.25 packet TNC for your computer's soundcard, can be used in place of the AGWPE software mentioned in this article. Either program will work but the setup in UISS differs for the UZ7HO software.

To get started using this optional approach, get the UZ7HO Soundmodem from **uz7. ho.ua/packetradio.htm**. Download and unzip these files:

• **soundmodem95.zip 02-Aug-16 08:20**
• **user_guide_v045b_EN.pdf**.
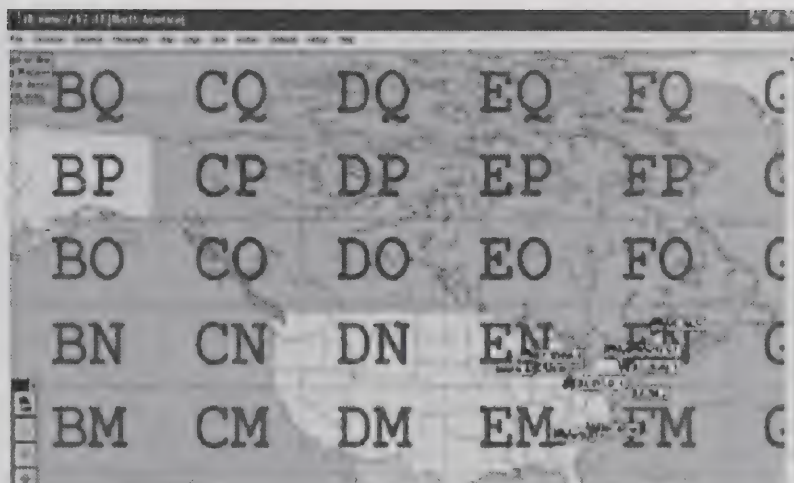


Figure 9 — UI-View APRS application showing station locations.

The setup guide and user guide are easy to follow. It is easy to test the UZ7HO Soundmodem. I tuned my receiver to the 144.390 MHz APRS frequency. I immediately saw the APRS messages. Good! The setup is receiving. I tuned back to 145.825 MHZ or 437.550 MHz ARISS packet frequency to wait for the next ISS pass over my station.

## ISS Operating Hints

• Listen before transmitting. The most prevalent mode is digipeat mode on

145.825. If you want to make a voice contact, listen to 145.80. Do not call until you hear voices; then make sure they are not from confused ground based operators.

• Keep your Keplerian elements up to date. The ISS repositions itself quite often. Check the AMSAT website Pass Predictions page **www.amsat.org/ track/index.php** or other sources for current ISS keps every few days.

• Be patient, a large number of hams are
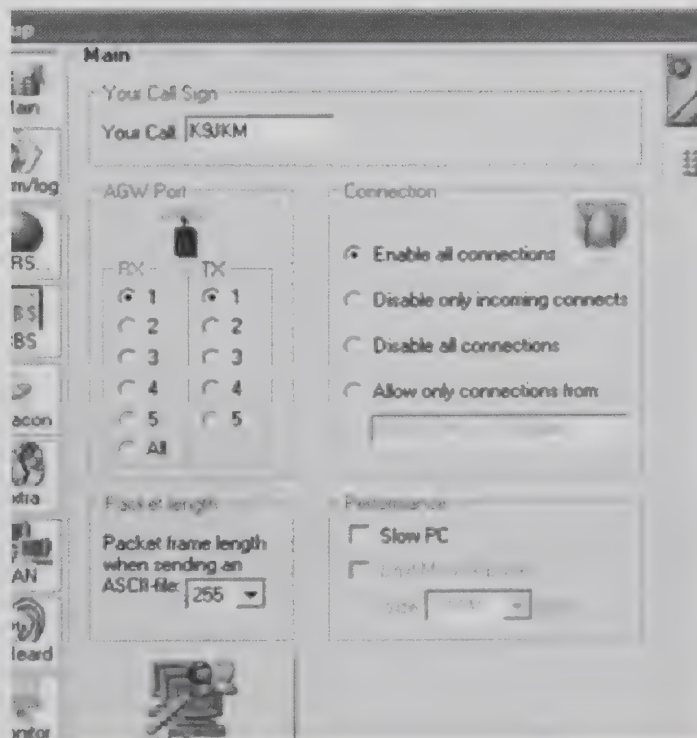


Figure 10 — The UISS program will require settings to be changed to operate with UZ7HO Soundmodem: In UISS top menu, select Setup >UISS>LAN (above screen).

just as anxious as you to communicate with the ISS.

• Keep your calls short and pass along your name, call sign and grid square.

• Up to date QSL information can be found on the ARISS web sites.

• The ISS is in process of upgrading the ARISS station, so check the web sites **ariss.org** or the AMSAT website's Current Status page **www.amsat.org/status/**

## Resources

www.ariss.org
www.issfanclub.com/
www.nasa.gov/mission_pages/station/multimedia/index.html (great ISS photos)
spaceflight.nasa.gov/station/reference/radio/index.html
www.arrl.org/amateur-radio-on-the-international-space-station
www.amsat.org
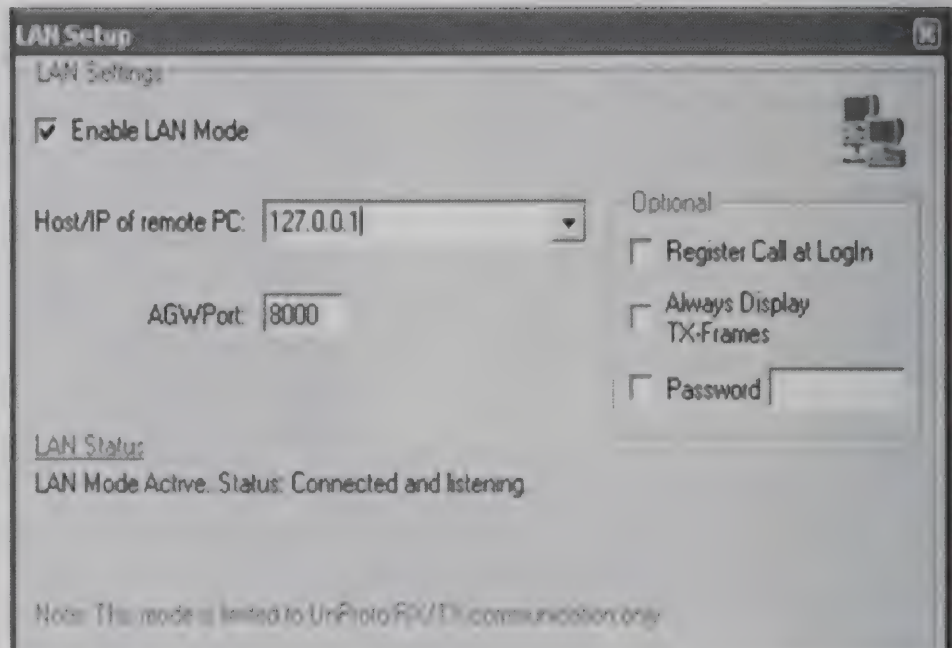


Figure 11 — In LAN setup, click on *Enable LAN Mode* Host 127.0.0.1 Port 8000.
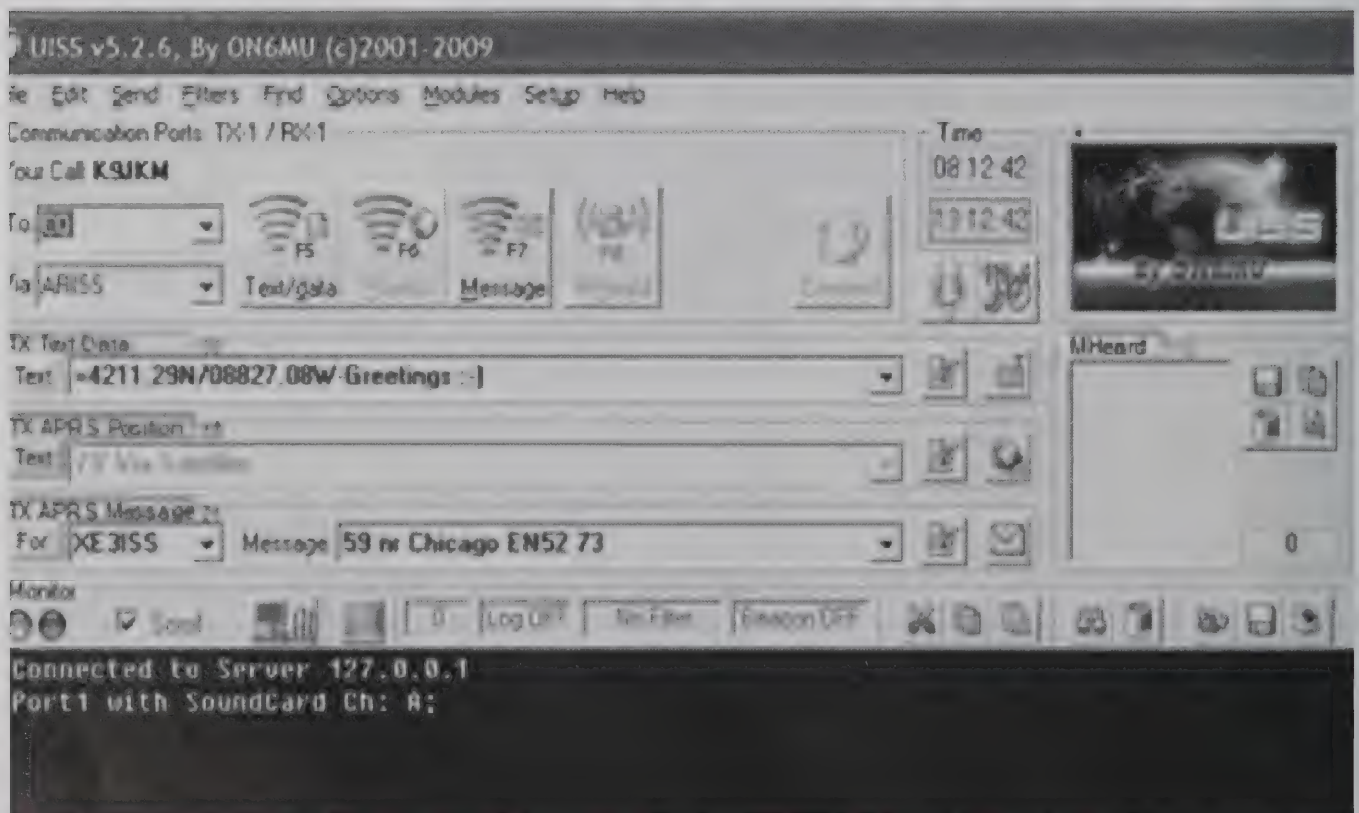


Figure 12 — UISS may prompt you to restart. Go ahead and restart UISS. To return to operation with the AGWPE software, unclick the Enable LAN Mode option and restart UISS. Your setup is now ready for the next ISS pass! To send your APRS position report, click on the UISS Text/Data button. You can enter custom messages for quick packet contacts with other stations into the TX APRS Message box and then click on the Message button.

# Working Digipeaters with the Kenwood TH-D72A and TH-D74A

By Joe Kornowski, KB6IGK
Editor, and
Patrick Stoddard, WD9EWK
Lead Area Coordinator

## THE RADIOS

For satellite operators intending to work packet/APRS mode with a handie-talkie (HT), the Kenwood TH-D72A and newer TH-D74A offer several compelling benefits. Both include built-in TNC and GPS features, and a similar setup. Both the D72 and D74 also allow for five "Status Text" fields that can be transmitted with the operator's position.

In terms of the D74's advantages for working packet/APRS, its color transflective TFT display puts more data on its larger screen, which Patrick prefers. More information on one screen cuts down on the need to page through a series of screens to see information that can't fit on one D72 screen.

The D74 also allows three "other" packet paths (only one in the D72), and up to 20 "phrases" (the D72 permits up to 8); "phrases" are short strings of predefined text that quickly can be pasted into a message to facilitate a QSO, as discussed below. See Figures 2 and 3. The other settings are the same between the two radios. Also, the D74 keypad is softer than the D72, making it easier to use during busy passes when trying to send and receive APRS messages, as well as view screens like the station list.

The one drawback for some packet operators using the D74 may be its inability to access the TNC's "cmd:" prompt, which was available in the D72 and D7. The D74 has a KISS mode, which is compatible with many packet programs that do not need to operate like an old-style terminal program.

Among the differences that do not directly affect packet/APRS operation, only the D74 provides:

- 222 MHz band, in addition to 2 meters and 70 centimeters
- an all-mode receiver
- Bluetooth,
- D-Star compatibility, and
- A MicroSD that allows voice or packet signal recording.

While the D74 importantly lacks the D72's cross-band full-duplex capability, packet operation is unaffected. A comparison and review of the two models appears in Patrick's post on QRZ.com's Satellite and Space Communication forum.

## Digipeating Satellites

Currently, the International Space Station (ISS) and PSAT are the only fully operational and most-used digipeating satellites. A list

| Channel | Receive (MHz) | Transmit (MHz) | Offset |
|---------|---------------|----------------|--------|
| 1 | 437.560 | 437.540 | -0.02 MHz |
| 2 | 437.555 | 437.545 | -0.01 MHz |
| 3 | 437.550 | 437.550 | (no offset, simplex) |
| 4 | 437.545 | 437.555 | +0.01 MHz |
| 5 | 437.540 | 437.560 | +0.02 MHz |

Table 1 — Necessary Doppler adjustments for 70 cm ARISS digipeater.



Figure 1 — The Kenwood TM-D710GA radio is shown on the right side of the Interoperable Radio photo. Also, you can see the AMSAT-built power supply (in white) and the load simulators (to the right of the power supply) and power sources to the left of the power supply. [Courtesy of ARISS.]

**Figure 2.**



**Figure 3.**

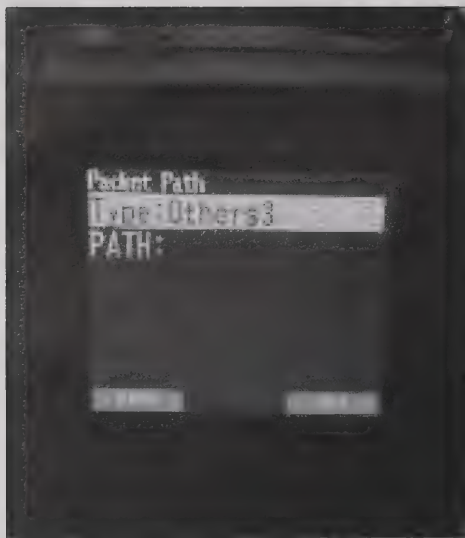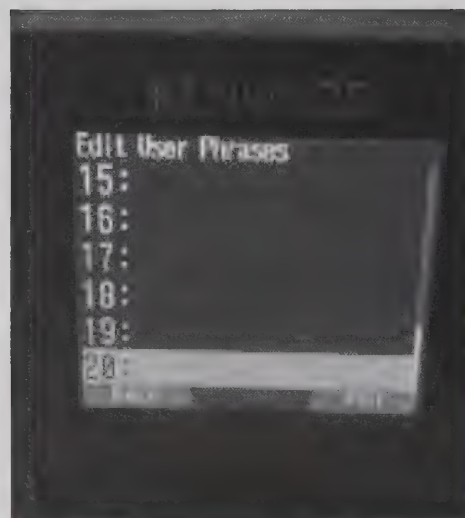of currently orbiting packet satellites, as well as those planned for future launch and deployment, appears on Bob Bruninga's (WB4APR) website at www.aprs.org/astars.html.

## ISS

ARISS (Amateur Radio on the International Space Station) has provided a packet/APRS digipeater on the ISS since 2007. That digipeater traditionally has operated on 145.825 MHz, considered the global APRS satellite channel, which obviates the need for Doppler tracking.

Unfortunately, the Ericsson VHF HT that served the ARISS packet operation in the European Columbus Module failed in October 2016. Subsequently, the UHF twin of the failed radio, an Ericsson UHF HT, was put into service in the Russian Service Module using 437.550 MHz. The change to 70 cm now requires users of the packet

digipeater to make Doppler adjustments on both the uplink and downlink, as depicted in Table 1.

To program these adjustments on the D72/D74, the operator creates a simplex receive frequency, then uses the VFO to set the transmit frequency and store it to the same memory channel, just as with any other memory. However, for this "odd split," in addition to pressing >OK to store the frequency as the final step, the user must first hold down the PTT button and then press >OK.

To remember these stored channels, the operator might name the saved memory locations for these split frequency pairs something like ARISS U1, ARISS U2, etc., with "U" designating UHF. Saving the original ARISS VHF frequency, which is also the PSAT frequency, as "ARISS V" (for VHF) reinforces the fact that PSAT uses "ARISS" instead of its own name, "PSAT," for the packet path. Additionally, the ARISS V designation may serve as a reminder that the original VHF digipeater frequency will be restored as the ARISS team is planning to deliver a replacement Kenwood D710GA radio to the ISS in late 2017.

## PSAT

PSAT (aka NO-84 and PSAT-1) launched in May 2015 and can digipeat packets just like the ISS. One challenge is that NO-84's digipeater is not always on, and operators must watch for its callsign to know the digipeater's status. The "PSAT" callsign means the digipeater is on, and "PSAT-1" means it is off.

Additionally, with only a 350 mW transmitter, the digipeater is fairly weak compared to the ISS. This makes low-elevation passes more difficult to work with the D72/D74, and virtually impossible without an Arrow or Elk antenna.

The ISS and PSAT transponders deliver packets worldwide through the global network of volunteer IGATE ground stations that feed the two downlink capture pages, psat.aprs.org and ariss.net.

## Set-up and Operation

Proper radio setup is essential for packet. Although not all that intuitive, at least the same setup applies to operating packet on both the ISS and PSAT. The basic steps for setting up satellite packet/APRS on the Kenwood HTs might look something like this:

1. *Your call sign* — Press the Menu button, select APRS, #300 - BasicSet, then My Callsign. Enter your callsign followed by the SSID number, e.g., KB6IGK-7, where 7 designates an HT or other portable use, or choose any appropriate number for your icon designation.

2. *The beacon* — Using the initial steps in 1 above, under menu #3D0 - TX Beacon Method, for the Initial Interval, select Manual.

3. *Baud rate* — Menu #311 – Int.TNC, for Data Band select A-Band; for Data Speed, select 1200 bps.

4. *Position comment* — Menu #380 – PositionComment, select In Service or Special or Custom #; just don't select Emergency.

5. *Status Text* — Menu #390 StatusText, user entry area for up to 42 alphanumeric characters, along with the number of times it is sent.

Patrick uses the Status Text field with a 1/1 TX rate, where it is sent every time his position is transmitted, so there is some readable text besides his callsign. For text, the operator can enter a "CQ" call, or his callsign with some other information (e.g., location), or a line of text explaining his activity (hamfest, rare location, NPOTA, etc.).

When working stations through the ISS or NO-84 digipeaters, the

StatusText field can be used either to identify the operator and the digipeater or to show the operating location. For example, for NPOTA activations in 2016, Patrick used the NPOTA site number and grid locator in this field. Stations would then note that he was doing a NPOTA activation, and see his location.

6. *Packet/APRS path* — Menu #3H0 – PacketPath, for Type, select *Others; for Path, enter ARISS, which should work for both the ISS and PSAT as described above.

7. *Message* — Press MSG button twice to bring up MSG Input, enter the callsign of the target station and a text message.

8. *Phrases* — Menu #3P0 - This allows the operator to create short predefined

phrases that can be copied and pasted into the MSG Input text field.

9. *TNC* — The TNC button will activate the internal TNC in either of two modes, APRS 12 or Packet 12. Pressing the button toggles between those modes and off. Select APRS 12 for satellite operation.

10. *Antennas* — Arrow and Elk work best for both satellites. A long duckie like the Diamond SRH77CA or telescoping whip also can work for ISS digipeating. The ISS has a stronger downlink than NO-84, which makes a big difference when trying antennas like the long duckies or telescoping whips.

Two-way messages are needed to complete a QSO via APRS. To avoid having to enter messages manually, Patrick uses the predefined "phrases." He uses a minimum of 3 "phrases" to make exchanges via APRS messages:

1. "Hi from [grid/grids] in [state]"
2. "TNX for call. [grid/grids] in [state]"
3. "TNX/73"

To automate the process of entering a callsign, Patrick uses the heard stations list to start sending messages. If a station isn't sending APRS-formatted packets, the operator will not be able to see it in the station list. An APRS message to that station will require manually entering the callsign and the message (or using a a predefined phrase).

After sending the first message to start a potential QSO, Patrick looks for a response from the other station, which would be followed by sending the third message. This is similar to the rapid-fire exchanges of grid locators on the FM and SSB/CW satellites. If a station calls via APRS message, Patrick will reply with the second message. He then should see something from the other station like his third message to confirm that his reply was heard. If he sees a signoff message from the other station, he may send his third message to wrap up the QSO.

He usually keeps a couple of additional messages stored in his radios. One has a brief description of his station. Another says "Please use APRS msgs for QSOs," as the APRS-ready radios will not display freeform text typed into a terminal program. The APRS-ready radios expect APRS-formatted packets — positions, messages, or beacons — and may only show a call sign without the rest of the packet when a non-APRS packet is received.

When sending APRS messages, an operator will sometimes see an "ack" come from the other station. This confirms that the other station received the operator's messages. Patrick does not use "ack" responses to decide if a QSO was made because those are automatically generated by the radio or software used by the other stations. Some stations will use automatic responses, which are normally prefixed by "AA:" followed by text. He doesn't log these as QSOs because he cannot determine if there is an operator on the other end. This is like working the old ROBOT on the RS satellites, where the satellite was capable of making a basic CW QSO. 🌐
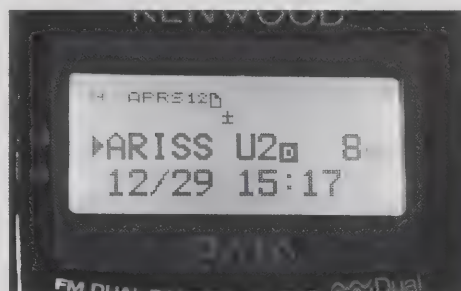


**Figure 4 — KB6IGK using TH-D72A, tuning to second frequency (U2) in early part of ISS pass. [All photos Joe Kornowski, KB6IGK, unless otherwise noted.]**
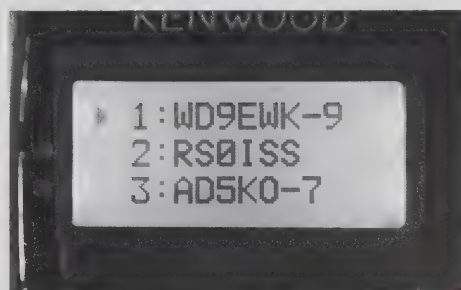


**Figure 5 — Station list showing a received position beacon from WD9EWK-9.**
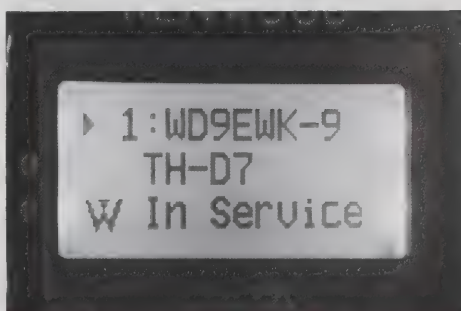


**Figure 6 — Position Comment from WD9EWK-9.**
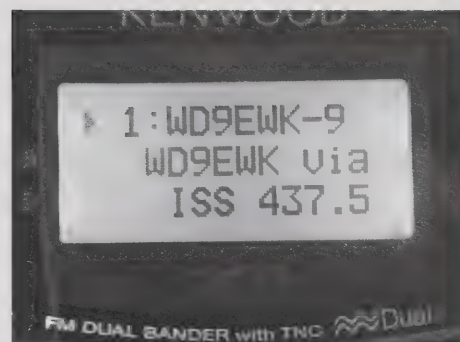


**Figure 7 — Status Text from WD9EWK-9, p. 1.**
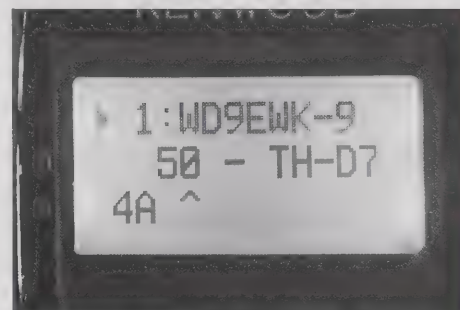


**Figure 8 — Status Text from WD9EWK-9, p. 2.**
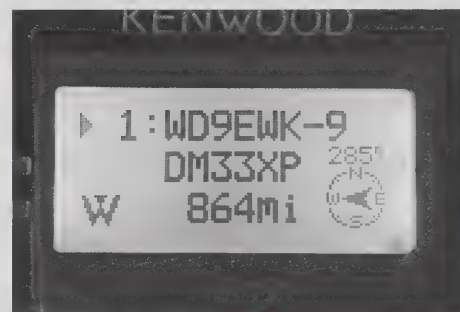


**Figure 9 —** APRS grid location and distance/direction from WD9EWK-9.
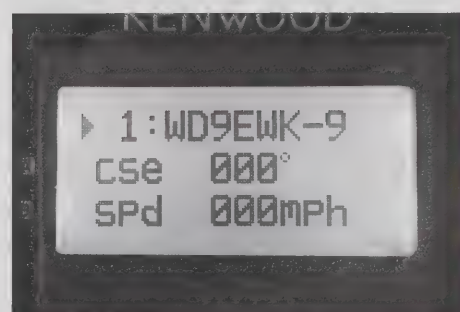


**Figure 10 —** APRS moving direction and speed of WD9EWK-9.
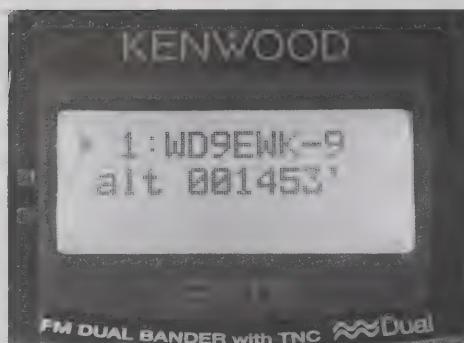
Figure 11 — APRS altitude of WD9EWK-9.



Figure 12 — APRS position data from WD9EWK-9.



Figure 13 — First digipeater (F) showing ISS callsign.
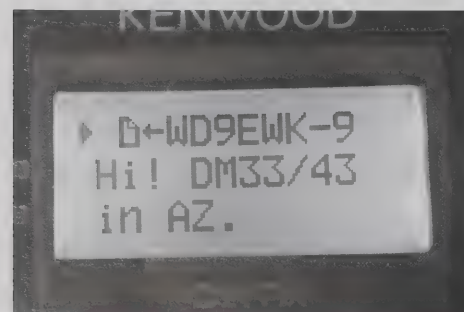


Figure 14 — WD9EWK's initial message to KB6IGK.



Figure 15 — Reply message sent to WD9EWK.



Figure 16 — WD9EWK QSL to KB6IGK.
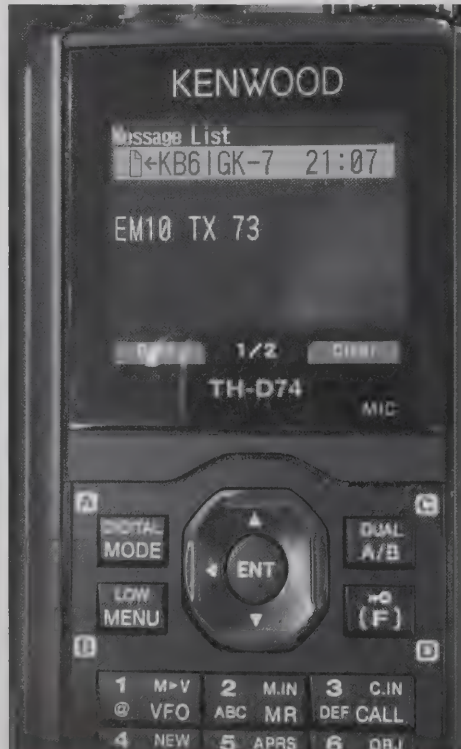


Figure 17 — WD9EWK's TH-D74 showing message from KB6IGK. [Patrick Stoddard, WD9EWK, photo.]
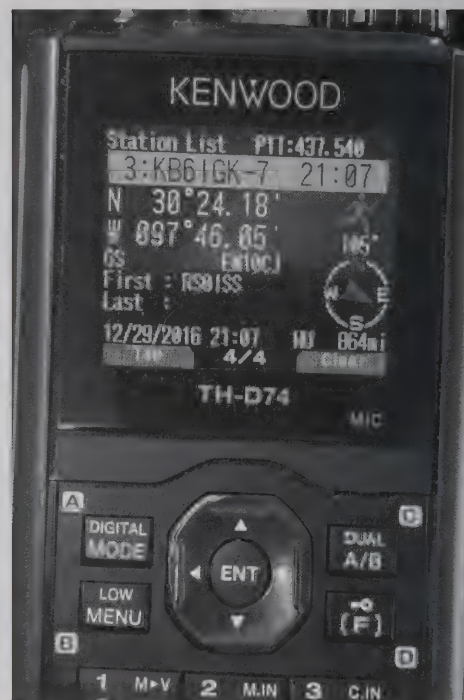


Figure 18 — KB6IGK shown in WD9EWK's TH-D74 station list. [Patrick Stoddard, WD9EWK, photo.]



Figure 19 — TH-D72 with Diamond SRH77CA.

# Finding Veronica[1]: Methods for Obtaining Recordings of Satellite Passes and Searching for Fox-1 Satellite Telemetry Beacons

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*Two methods for obtaining recordings of satellite passes and a new approach for finding Fox-1a (and other) satellite telemetry beacon signals on an FM downlink using non-telemetry known reference signals*

Fox-1a sends down telemetry in three different ways: data-under-voice telemetry sent simultaneously with the user transponder audio, data-under-voice telemetry sent with a regularly scheduled voice ID beacon after a two minute period of inactivity and data-under-voice telemetry sent with a safe mode ID voice beacon. The voice IDs are prerecorded audio where Veronica[5] announces "Hi, this is amateur radio satellite Fox-1" or "Fox 1 safe mode."

In all three modes, the FM downlink contains a data-under-voice telemetry sent simultaneously with the transponder audio, but the telemetry is lower in frequency than the transponder voice audio. In the first mode, the downlink is FM modulated and the users sending their voices through the transponder are effectively an "unknown spreading" of the FM signal's frequency when viewed at RF. We don't know what they're saying, so we can't know how to remove their voice from the FM signal at RF digitally. If we FM demodulate the signal, then we can separate the audio with the voices and the audio with data.

In the other two modes, the beacons contain a short burst of unmodulated carrier just before the data. Due to the electronics, the carrier is not at a steady frequency but "swishes" several kilohertz. This is called the "fox tail" due to its appearance on a waterfall display and its resemblance to the curved tail of an actual fox. That unmodulated swishing carrier is a unique and detectable signal on an SSB or SDR receiver. However, if a particular ground station is using an FM receiver, then that unmodulated swishing carrier is (probably) not as noticeable or detectable as the longer voice ID transmission containing Veronica's voice. If the ground station only has FM reception, then the combined telemetry and voice ID audio will be the only audio for a telemetry program to process. Detecting and identifying the unmodulated swishing carrier on an FM receiver, perhaps by detecting the relative silence and looking at the slope of the changing voltage output from the FM discriminator, is left as an exercise to the reader. Measuring the frequency of the "fox tail" carrier, calculating Doppler, TCA, and eventually, TLEs is a separate project by the author.

## One Man's Trash, Another Man's Treasure

Much like the truth, whether something is signal or noise depends greatly on your point of view.[2] If you only want to use the FM voice transponder, then the telemetry beacon's signal (the subaudible "data under voice" data below about 300 Hertz) is noise to you. It would normally be filtered out by the audio filters in the FM receiver, so you probably will not hear it much, if at all. However, if you only wanted to receive the telemetry beacon, then the voices heard above 300 Hertz are the noise that has to be filtered away.

After FM demodulation, the user voices are above 300 Hertz, and the telemetry is below 300 Hertz. If the signal is weak the forward error correction (FEC) will help, but can we help it further, particularly for telemetry sent after inactivity or in safe mode. One of the problems is determining when a telemetry frame starts. The Fox-1 telemetry downlink doesn't contain a SYNC vector to help identify the presence of telemetry signals, and the start of frame byte is only eight bits, so it is easy for it to be corrupted by noise or for noise to impersonate the expected eight bits.

Success is sometimes defined as turning a disadvantage into an advantage. We don't know what the users are saying, so their added energy to the downlink signal is a disadvantage. If only we knew what they were going to say before they say it, then we could digitally subtract it out as we hear it. If we knew what they were going to say, we could even use that known audio to search for the satellite signal, which might be useful if the satellite is running with a low power output in safe mode and we're searching blindly for its signal.

We do know what the audio will be when the audio is a recording of Veronica. When the satellite is in beacon mode or in safe mode you can hear the prerecorded audio from Veronica, the voice of Fox-1, saying "Hi, this is amateur radio satellite Fox-1" or "Fox-1 safe mode." We have the original recordings for both as "Veronica Fox-1.wav" (4.1 seconds) and "Veronica Safe Mode. wav" (about 2 seconds). Instead of looking for a SYNC vector, which we don't have, or looking for the start of telemetry byte, we could look for Veronica. The author is working on a method using correlation with FFTW and libxcorr or another correlation package to identify Veronica in the downlink recordings. Her voice begins at the start of the second telemetry frame, so finding the start of Veronica's audio finds the second telemetry frame, and since the size of the frame and the bit rate is known, we can calculate backwards to find the exact start of the first frame. Veronica is or will be present on all of the Fox satellites, so this method will not be limited just to Fox-1.[5]

## Telemetry Beacon, Telemetry Beacon, Where for Art Thou…?[3]

While the telemetry reception is excellent over the U.S., Europe, and some other places, there are still large gaps over sections of the planet. If we only had more ground stations that could receive the signal, we could cover the gaps. There are several ways to get the data, but in simplest terms, you can either do it yourself or get other people to do it for you.[6] The former has the problem of poor spatial diversity whereas the latter has some limitation on how much data you can pull across the network. IQ recordings can get quite large.

One method to get recordings is to use the WebSDR network of receivers at www.websdr.org. This page lists a collection of currently active SDR receivers that can be connected to the Internet with options to filter by band and region. For Fox-1, filter by "2m" for the two-meter downlink. This displays a list of receivers that can receive two meters (although some receivers can receive on two meters but cannot receive the frequency of the Fox-1 downlink). The station listing also includes the Maidenhead grid square where the receiver is located, so it's possible to compute satellite passes for Fox-1 for this receiver. A map also shows the locations of the stations.

Now we know of the existence of multiple ground stations, and potentially multiple satellites to track. This brings up the next problem: which satellite will appear next over which ground station? Assuming we know the Maidenhead grid squares of the receivers, the TLEs for the satellites and that we have Linux, bash, and predict, then we can write a simple script to compute all of the next passes at each location and find out which one is next. For each ground station, create a qth file for predict with the name, latitude, longitude and elevation in the file. Run predict using that station's location to obtain that station's next pass information, saving it to a unique file.

```
echo 'Calculating passes for 2m satellites'
groundstations=(IO91of GG56tv ka2upw
KG43ar JN78sk)
satellites=(AO-85 UKUBE-1 UO-11 ISS
DO-64 AO-73)
for gs in "${groundstations[@]}"
do
```

```
for sat in "${satellites[@]}"
  do
    echo -n $gs $sat...
    predict -t amsat.tle -q $gs.qth -p $sat -o
next-$gs-$sat
    echo -n ...
    ./summarize-satellite-pass.sh next-$gs-
$sat $gs $sat >> summary
    rm next-$gs-$sat
    echo Done.
  done
done
```

Then combine all of the lines output from predict for that location to determine the start, end, and maximum elevation for that pass.

```
AOSunixtime=0
AOSdate="
AOStime="
LOSunixtime=0
LOSdate="
LOStime="
maxel=-1

while read p; do
  currentunixtime=`echo "$p" | cut -d'' -f1`
  currentdate=`echo "$p" | cut -d'' -f3`
  currenttime=`echo "$p" | cut -d'' -f4`
  currentelevation=`echo "$p" | tr -s '' | cut
-d'' -f5`

  if [ "$AOSunixtime" -eq 0 ]; then
    AOSunixtime=$currentunixtime
    AOSdate=$currentdate
    AOStime=$currenttime
    LOSunixtime=$currentunixtime
    LOSdate=$currentdate
    LOStime=$currenttime
    maxel=$currentelevation
  fi
  if [ "$LOSunixtime" -lt "$currentunixtime"
]; then
    LOSunixtime=$currentunixtime
    LOSdate=$currentdate
    LOStime=$currenttime
  fi
  if [ "$maxel" -lt "$currentelevation" ]; then
    maxel=$currentelevation
  fi
done <$1
echo $AOSunixtime $LOSunixtime
$AOSdate $AOStime $LOSdate \
  $LOStime $maxel $2 $3 $4 $5 $6 $7
```

The only problem left is to connect (manually) to the appropriate websdr station at that right time, set the receive frequency exactly and start recording the FM audio. The author is currently trying to find a way to either automate the WebSDR recording programmatically or get the recordings some other way. Obtaining raw I and Q instead of FM demodulated audio is another unrealized goal. As a proof of concept, the author was able to record audio from a websdr station in KG43 and later extract the telemetry using FoxTelem and upload it to the Fox-1A telemetry leaderboard.

## Doing it All Yourself

On the other hand, you can make the recordings yourself using just a Raspberry Pi running Linux and an inexpensive RTLSDR dongle. There's a simple script called "sdrrecorder.sh"[7] that will record at a predetermined time and frequency. I started with this script and made some modifications.

If you set the center frequency of an RTLSDR dongle near 145.180 MHz, then the bandwidth of the receiver will extend from about 144.180 MHz to about 146.180 MHz. This fully covers the 145 MHz satellite subband from 145.8-146.0 MHz, but it also extends low enough to include the APRS network at 144.390 MHz and leaves enough room at the edges so that SDR programs like SDRSharp can still process the signals in the recording. The presence of any APRS signals at the lower end in the IQ recordings will assure you that you recorded the correct range of frequencies and that the receiver, preamp, and the antenna are working as expected.[4] This would be particularly useful information if you didn't find any satellite signals in the recording.

Under Linux, we use the rtl_sdr program to record the samples, but there are a couple of limitations to overcome. If we want to record at 2,048,000 I/Q samples per second, then we will be creating some rather large recordings. Usually, we would use the "-n" parameter to tell rtl_sdr when to stop, but the parameter for "-n" is only a uint32 representation. The longer satellite pass recordings will quickly get more samples than the biggest sample number we can pass in for "-n." If you leave off the "-n" parameter when starting rtl_sdr, then the recording will keep running, and it won't ever stop. We still want to stop the recording after the pass is over, so we can create a pipe and use the Linux/bash "head" program to end the recording since "head" does support really big numbers. This means that we have to precompute how many samples we want in the whole recording. Another problem with the large recordings is that some filesystems have a maximum file size of about two gigabytes. In particular, the author wanted to record to a USB thumb drive rather than the Raspberry Pi's SD card because it would be faster and easier to move the thumb drive to another computer in a different room instead of copying gigabytes of recordings over the home network.[8]

Even with a larger maximum file size in the Linux filesystem, it is not possible to put one long recording into one file. The solution is to split up the file into separate recordings. We don't want to stop and restart rtl_sdr because then we could miss something. We just want to separate the data stream into different files. If we record I and Q at 2,048,000 samples per second, then one minute is 245,760,000 samples. Having separate recording files also makes it easy to jump to the middle of the recording if your SDR program doesn't support a "fast forward" into the middle of the recording. Putting this all together we end up with this command line:

```
rtl_sdr -f 145180000 -d 0 -s 2048000 -p 0
-g 0 - |
head --bytes='$totalsamples |
split --bytes= 245760000 --suffix-length=2 \
--numeric-suffixes - '$rawfilename
```

Where 145,180,000 is the receiver frequency, 2,048,000 is the sampling rate, $totalsamples is the total number of samples that will be in the recording, and 245,760,000 is one minute's worth of samples. I have written a "rtlrecord.sh" script that creates a second script and schedules the execution of the second script at the appropriate time.

```
#!/bin/bash
#
# rtlrecord.sh - schedule a RTL dongle
recording
#
# (c) Copyright 2016 Douglas Quagliana
KA2UPW
#
# Usage:  rtlrecord satellite-name hh:mm
mm/dd/yyyy
#             minutes-to-record filename-
to-record-to
#
if [ -z "${5}" ]; then
  echo Usage: $0 " satellite-name  hh:mm
mm/dd/yyyy  minutes-to-record filename-
to-record-to"
  exit
fi

# Two-meter satellite subband is 145.8 to
146.0 MHz but here we
# just record the whole two-meter band
# at maximum sampling. This has several
advantages: we get
# everything on two meters including all of
# the satellites that we can hear above the
horizon, we get
# the APRS network on 144.390 and we
don't
# have to worry about what the exact ppm
error is on the
# frequency. We also pick up nearby
repeaters
# and everything else on two meters.
# Record at max sampling rate for several
reasons: this lowers
# the noise on the desired signs, gives us
# more samples to work with to extend the
significant bits
# beyond the 8-bit ADC, and (the best
reason
# of all to record the half of the two-meter
band: because we can).

samplingrate=2048000        # maximum
```

sampling rate for RTL dongle.
```
        # Any higher and the dongle starts to
        # drop samples
donglenumber=0
        # RTL dongle number
gain=0
        # gain to be used 0=automatic-gain
ppm=0
        # ppm correction
destinationfolder=/usbdrive
        # destination folder (probably needs to
        # be a command line parameter)

# number of samples per minute (the "2" is
I and Q);
# let is required here
let bytesinoneminute=60*$samplingrate*2

# minutes*(60sec/min)*samplingrate*2 (the
"2" is I and Q);
# let is required here
let totalsamples=$4*60*$samplingrate*2

centerfreq=145180000
# for amateur satellites
#centerfreq=137500000
# for weather satellites

# Build the script that we will give to the
"at" command
# for running "at" a specific time
# The script will look something like this:
#
# build the filename for the script and the
raw recording
filename=$(basename "$0")
filename="${filename%.*}"

# user provides us with something like 12:34
01/23/2016
# but we want something like 20160123_1234
for the filenames
datetime=$3
YYYYMMDD=$(date --date=$datetime
+%Y%m%d )
HHMM=$(echo $2 | tr -d ":")

# Use these names for amateur satellite
recordings
shfilename="./"$filename"_"$1"_"$YYYYM
MDD"_"$HHMM"Z.sh"
rawfilename=$destinationfolder"/"$1"_"$Y
YYYMMDD"_"$HHMM"Z_145180000
Hz_IQ_2048000SPS_min"
logfilename=$destinationfolder"/"$1"_"$Y
YYYMMDD"_"$HHMM"Z_145180000
Hz_IQ_2048000SPS.log"

# Create the script that will be sent to "at"
to do
# the actual recording
echo '#!/bin/bash' > $shfilename
# script will log the starting time of the script
to the logfile
echo 'echo Starting > '$logfilename >>
$shfilename
# script will put the actual date/time into
the logfile
echo 'date >> '$logfilename >> $shfilename
```

```
# Just record about half of the two-meter
band centered on about
# 145 MHz. We want APRS on 144.39 and
the satellite subband at
# 145.8-146.0. rtl_sdr -n parameter is uint32
so that it won't take
# really big numbers. Use the "head" program
to end the recording
# since it DOES support really big numbers.
# split on 245760000 bytes is a split once
a minute
#
# There are a couple of problems with
recording at 2.048M SPS:
# -non-Unix filesystems like the kind you
find on a regular USB
# drive have a maximum filesize of about
2GB. This is too small
# for some of the satellite passes.
# -rtl_sdr uses uint32 for -n so you can't tell
rtl_sdr to
# record a huge file.
# -if you put everything in one file, and the
interesting part
# is in the middle then you'll wait forever
for one of the
# SDR software programs to "play" the
recording to get to the good
# part. Splitting every minute lets you
concatenate just the
# minutes you want and then run sox2wav
# on just those minutes. This will also be
useful later for blind
# searches - easier to parallelize on smaller
piecemeal recordings.
#

# for 2m amateur use this (for weather
satellites change frequency)
echo 'rtl_sdr -f 145180000 -d '$donglenumber
'-s '$samplingrate '-p '$ppm '-g '$gain ' - | \'
>> $shfilename
echo 'head  --bytes='$totalsamples ' | \'
>> $shfilename
echo 'split --bytes='$bytesinoneminute'
--suffix-length=2 --numeric-suffixes -
'$rawfilename >> $shfilename
```

```
echo 'echo Ending >> '$logfilename >>
$shfilename
# script will put the actual date/time into
the logfile
echo 'date >> '$logfilename >> $shfilename

# Note: the .sh file we are creating needs to
be on a *ix
# filesystem for us to run chmod on it. If
you put
# the .sh file onto the usbdrive you cannot
chmod it.
#
chmod a+x $shfilename
#
# Schedule the script to run at the right time
at $2 $3 -f $shfilename
```

The final "at" line will schedule the execution of the script that was just created. At the appropriate time, the recording will be started and then stopped on the RTLSDR dongle. With luck, it contains the audio from the satellite of interest.

## Future Work

How about a phased array of multiple RTLSDR dongles? Recently the hardware side became easier with the new V3 dongles that rtlsdr.org sells online. Why phased array? Why RTLSDR dongles? First, these receivers are extremely cheap. Second, at two megasamples per second I/Q sampling, we easily get the entire two-meter satellite subband (or any two megahertz of the 70 cm band). With the phased array we get several additional advantages. Combining multiple signals gives us gain over a single RTLSDR. By phasing the signals (in software) we can create directional reception beams (beamforming) to listen with gain in a particular direction. We can do this in real time, or we can record the signals from all of the RTLSDR dongles (e.g., with a Raspberry Pi or two) and then do the beamforming later on a machine with a faster processor.



**Figure 1 – from www.websdr.org showing SDR stations that can receive at least some of the two-meter band. Map by Google Maps.**

With SDR IQ recordings we can rerun the beamforming again but point the reception beam in a different direction. We can re-run the processing on the recordings multiple times with different beams on the same recording. This means we can record the two-meter satellite subband once then reprocess it as many times as we want to extract as many satellite signals as we want. Suppose two or more satellites were above the local horizon at the same time. With a steerable Yagi, you have to choose one or the other in real time, and that choice is fixed forever. You can't decide later that you really wanted to listen in a different direction to a different satellite. With recordings from a phased array, you can point (and steer) a beam at both. You can go back in time and rerun the pass pointing in a different direction. A (huge) archive of SDR recordings also gives us archeological capabilities. Was this satellite transponder ON last Tuesday at 0400Z?

There are still a few complications, because even with the sampling clocks synchronized, the phase of the local oscillators on the individual dongles will vary, but can be corrected in software once known. A proof of concept of using three dongles in a phased array has already been demonstrated.[9] Comments, constructive criticism, and copies of your recordings from the Fox satellites are welcome.

## Footnotes

1 Finding Veronica – well, because Nemo and Dory were already found by Walt.
2 Guinness, Alec, actor. *Star Wars: Episode VI - Return of the Jedi*. 1983. Lucasfilm, 1983.
3 Apologies to Bill and Jules.
4 Using the APRS on air signal as test signals to verify that everything is working correctly was inspired by a technique used by the SETI@home project. They inject test signals into the telescope receiver to verify that their hardware and software are working as expected. Compare the APRS signal waterfall to figure 2 at **setiathome. berkeley.edu/sah_sci_newsletters. php?frag=news-6.inc**
5 Buxton, Jerry, N0JY. [The] Little Girl that lives aboard AO-85. amsat-bb mailing list. June 30, 2016.
**www.amsat.org/pipermail/amsat-bb/2016-June/059326.html**
6 "I Get I (and Q recordings) with a little help from my friends."
7 **github.com/michelinok/sdrrecoder/blob/master/sdrrecorder.sh**
8 "Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway."
Tanenbaum, Andrew S., *Computer Networks, 4th ed.*, p. 91.
9 "rtl_coherent: Synchronized RTL-SDR receivers." **github.com/tejeez/rtl_coherent.** ⊕

# Using DVB-S2X and Annex M to Implement Low-cost Phase 4B Earth Station Terminals

**Wallace Ritchie, WU1Y**

## Abstract

The AMSAT Phase 4 Ground Team has been evaluating DVB-S2, Generic Stream Encapsulation (GSE) and DVB-S2X extensions for use in the space to ground segment of the AMSAT Phase 4B Geosynchronous Satellite transponder. DVB-S2X provides extensions to an already complicated standard. However, use of the optional Annex M extension has the potential actually to simplify and reduce the computational complexity of Earth Terminals. This could potentially provide a significant reduction in the cost of low-end terminals in low manufacturing volumes with a resulting expansion of the population of Phase 4B users. This paper explores the DVB-S2X protocols and Annex M and how various features of these standards might be used to reduce the complexity of Phase 4B Earth Stations in the 10 MHz bandwidths anticipated for the Phase 4B downlink.

## 1. Introduction

The AMSAT Phase 4B project will place a Software Defined Digital Regenerative Transponder into Geosynchronous Earth Orbit (GEO) over North America. Unlike traditional bent-pipe transponders, which amplify and frequency-convert signals from uplink to downlink, the P4B transponder is essentially a full duplex cross-band digital repeater. There is no analog signal path from uplink to downlink. Instead, there is a multi-mode, multi-channel digital receiver bank and a single digital transmitter. A digital processing system forwards data from the multiple uplink receiver channels to the single channel downlink transmitter.

The specific functions performed by the P4B SDR Transponder will be determined by the Software and Field Programmable Gate Array programming uploaded from the ground. This allows these functions to evolve over time.

As currently planned, the satellite uplink will support more than 100 individual Frequency Division Multiplexed (FDM) carriers from individual ground stations with each carrier allocated within a 10 MHz uplink bandwidth. The downlink will be a single modulated carrier occupying the allocated 10 MHz downlink bandwidth. Digital data from the multiple uplinks will be received, demodulated, momentarily stored and then relayed over the downlink. This will provide digital simplex channels that can transport voice, messages, data, and IP traffic between earth stations in point to point or point to multipoint applications.

## 2. Digital Video Broadcasting

Digital Video Broadcasting (DVB) has been in use for nearly two decades to deliver Direct to Home broadcast television through GEO satellites. DVB is the most widely used digital transmission standard in the world. More than a billion DVB receivers are in use. Hundreds of millions of them support DVB-S/S2 based satellite transmissions. The DVB-S family of standards has evolved over the years as digital television has advanced from so-called Standard Definition, through High Definition and now to Ultra High Definition TV (UHDTV). Also, the standards have grown to support additional services enabled by the satellites, e.g., IP downlinks newsgathering and professional applications.

In the typical DVB-S broadcast application, a relatively high power Earth station originates the modulated digital carrier and a linear or quasi-linear transponder in the satellite filters and amplifies the weak receive signal, frequency translates to the downlink band and greatly amplifies the signal with a High Power Amplifier for re-transmission to the consumer ground stations. The basic configuration is a one-way point to multipoint.

The Phase 4A Package built by AMSAT-DL will be onboard the Qatar Satellite Company's Es'Hail-2 satellite to be launched into a geostationary orbit. Currently planned for the 3rd quarter of 2017, this spacecraft is to provide coverage over Africa, most of Europe and Eurasia. The AMSAT Phase 4A package will operate much like the traditional DVB-S broadcast application over its 8 MHz linear transponder.[1] This transponder will be used to provide a very small number of digital carriers from select stations including SDTV and HDTV transmissions. AMSAT P4A uses DVB-S/S2 more or less as intended – to deliver broadcast television. But P4A is also capable of transporting digital signals with suitable ground equipment (2.4-meter dishes, 100 W 2.4 GHz amplifiers).

In contrast, AMSAT P4B uses the DVB-S2[2] formats for a different purpose - to multiplex

all of the received uplinks into a single digital downlink carrier. Like AMSAT P4A, P4B can carry digital TV and Broadband Data. P4B, however, supports many narrowband digital uplinks using modest ground equipment.

The latest standards, DVB-S2, DVB-S2X[3], and the many optional features provided in their annexes provide an extensive menu of choices for P4B. While many of them look inviting – one just can't just consume everything on the menu. Choices must be made, and some of these choices are mutually exclusive.

## 3. Generic Stream Encapsulation (GSE)

Phase 4 Ground has been planning to utilize an optional DVB-S2 feature called Generic Stream Encapsulation (GSE)[4] to carry arbitrary Layer 2 MAC frames over the basic transport provided by DVB-S2 (or the even more flexible DVB-S2X). GSE provides a standard and efficient means to encapsulate IP packets for transport over DVB-S2 frames. Features include layer two-header compression optimized for IP.

The robust Forward Error Correction (FEC) specified in DVB-S2 delivers the extremely low error rates required for the delivery of Digital Television streams and high latency IP packets. At present, the P4B downlink is exclusively IP.

### 3.1 DVB-S2 Physical Layer

The Physical Layer of DVB-S2(X) has a relatively simple structure. Symbols are packaged into slots of 90 symbols. Additional "Pilot Blocks" of 36 symbols are optionally inserted periodically into the frame. The pilot symbols aid the receivers in timing recovery and symbol alignment.

Every physical frame begins with a 90 symbol[5] PLHEADER that provides a start of frame (SOF) sync pattern of 26 symbols and a MODCOD that indicates the modulation and coding for the frame. The MODCOD is protected by its own heavy forward error correction to insure that it is correctly decoded even in the presence of errors. When the specified MODCOD indicates the inclusion of pilot symbols, then 36 symbols of pilot occur after every sequence of 16 slots (1440 symbols).

The physical layer carries PLFRAME DATA that consists of a fixed number of scrambled FECFRAME bits. FECFRAME bits are the bits that result after Forward Error Correction (FEC) coding has been performed on a chunk of data. The number of bits produced by the FEC encoder is either 16,200 or 64,800[6] coded bits. The number of original bits in the data depends on the modulation and coding selected for the frame, and this can vary frame by frame. The MODCOD tells the receiver how many symbols of what modulation format to expect in the frame. For example, one of the heavily coded MODCOD indicates QPSK and ¼ RATE FEC with a Short FEC frame. With this MODCOD 3072 bits are input to the FEC encoder to produce 16200 coded bits which are then transmitted with 8100 symbols. This has an efficiency of 0.38 symbols per bit. One of lightest coded MODCODs indicates 32APSK modulation with 9/10 FEC. With this MODCOD, 58,192 bits are input to the FEC block to produce 64,800 coded bits which are transmitted at 5 bits per symbol using 12,960 symbols. This has an efficient of 4.5 bits per symbol. This covers an almost 12 to 1 range and allows a correspondingly wide range of signal to noise ratios to be accommodated by the system.

### 3.2 Baseband Frames (BBFRAMES)

BBFRAMES are the input to the FEC encoder. They have a length that is the same as the FECFRAME data. For each BBFRAME there is exactly one PLFRAME that will be transmitted. A BBFRAME includes an 80-bit Header that indicates what kind of data is in the frame. Since P4B downlink is planned to be all-IP, a BBFRAME will always contain only GSE packets.

### 3.3 GSE Packets

GSE Packets transfer the Protocol Data Units (PDU) from the Network layer. In P4B, a PDU is always an Ethernet Layer 2 packet, usually carrying an IP packet.

GSE packets cannot span multiple BBFRAMES, i.e. a BBFRAME must always begin with a GSE Packet header. However, the PDU that is being transported can be larger than a BBFRAME. Basically, GSE provides the means to transport PDU's by fragmenting them where necessary and packing them into GSE Frames that fit into BBFRAMES. The BBFRAMES are then FEC encoded and transmitted over the downlink as Physical Layer Frames.

The GSE Header provides all of the information necessary to reassemble the PDU's. It should be noted that GSE can handle fragmented reassembly for multiple interleaved PDU's. This allows the transmission of higher priority PDU's to interrupt the transmission of lower priority PDU's essentially. Whenever a high priority PDU is ready, the transport layer can begin sending its fragments at the next opportunity – even if the current PDU has fragments remaining to be sent. Many different PDU's can be in process in various states of fragmentation. This feature allows an effective Quality of Service (QoS) capability to be implemented. Phase 4B will likely use this capability to transport isochronous streams carrying digitized voice channels.

### 3.4 Fragmentation CRC

When GSE Packets are fragmented, the final packet in the sequence contains a cyclic redundancy check (CRC). This is identical to the Ethernet CRC. The CRC assures that the fragmentation and re-assembly process occurred without errors. The entire PDU is dropped if the CRC is bad. The CRC is not used when the PDU is not fragmented, i.e. the PDU fits into a single GSE packet.

Note that if it can be assured that a PDU will always be fragmented, then the CRC will always be present. This fact can sometimes be exploited to skip FEC processing for a PLFRAME.

### 4. Very Low Signal to Noise Ratio (VL-SNR) MODCODs

The combinations of modulations and coding rates in the base DVB-S2 standard are well suited to the Direct to Home (DTH) television application. Other applications, however, may require the ability to work at even lower signal to noise ratios. DVB-S2X adds a new capability applicable to those applications.

To support these DVB-S2X VL-SNR MODCODs, a special 10 slot VL-SNR header is inserted after the normal PLHEADER. Since there are always 90 symbols in a slot, this additional header is 900 symbols long. Receivers that don't need to handle VL-SNR use the normal SOH and decode the MODCOD which gives them the length of the frame as well as the location of the pilot blocks. This allows them to remain locked during the VL-SNR frame. The VL-SNR stations use a correlator approach to synchronize and lock to the 900 symbol sequence in the VL-SNR header. This allows them to maintain synchronization lock with the downlink despite a very low signal to noise ratio. The codes also indicate the modulation, coding, and spreading that will be used for the symbols in the frame.

To maintain compatibility with normal receivers, the VL-SNR frame sizes are adjusted so that they remain compatible with the number of symbols used by the normal MODCODs.

## 5. Phase 4B Terminals

Several types of earth terminals are envisioned for Phase 4B. At the low-end is a single channel narrowband voice terminal providing reasonably good quality voice and/or low speed data. These terminals will operate with about 10 kHz of uplink bandwidth using small dishes. The design objective is to drive the cost of such terminals as low as possible.

At the mid-range is a multi-channel wideband terminal capable of carrying trunked narrow band channels and/or higher speed IP packet flows. The mid-range terminal is the so-called "Amateur Radio Access Point" that can aggregate traffic within a local area, e.g., from multiple VHF/UHF repeaters and/or point-to-point links to the public Internet. These terminals will operate with uplink bandwidths on the order of 100 kHz.

At the high end are terminals with up to 1 MHz of uplink bandwidth. These will require higher power and larger apertures but will be capable of transmitting higher speed IP data streams, e.g., MP4 television.

## 6. Phase 4B Narrowband Services

Phase 4B will support voice services through the satellite for a large population of users. This is intended to provide point to point voice channels similar in function to SSB or FM voice channels used on the HF and VHF bands. Also, P4B will support low-speed data services equivalent to RTTY, PACTOR and PSK31. If a sufficiently low-cost terminal can be created, these narrowband services will account for the vast majority of connections.

Since 4B will be in GEO, the mean half-hop delay through the satellite is about 260 milliseconds before accounting for processing delays within the satellite. This is already at the high range of acceptable delay for voice. Some additional delay must be added to accommodate jitter buffers when interworking with traditional voice paths, e.g., VoIP.

Digitized Voice is essentially an isochronous application that requires a steady stream of packets with predictable delay and jitter characteristics. Packets that can't meet the schedule are generally dropped on the floor.

Typical digital voice is compressed in 20ms frames resulting in 50 packets per second. Tolerance to packet loss varies with codec type but is typically in the 1% to 5% range. Digital Voice has fundamentally different error performance requirements than digital TV or high latency IP traffic. The "cost" of an error in Digital TV or high latency IP is large. It destroys image quality or requires expensive re-transmission and delays for IP. This is why very strong error correction schemes are specified for DVB-S2. Voice, in contrast, involves very short packets (as low as 6 bytes per frame) and can tolerate losses of a few percent without major impact on perceived quality. Additionally, when multiple conversations are carried in a single packet, errors in the data that may affect one conversation may not affect others. This means that we potentially have the option of using a different approach to error correction for narrow band traffic. How this could work is discussed below.

## 7. FEC Coding

DVB-S2 uses a forward error correction scheme that performs close to the theoretical limit for the communication channel. This delivers the very low bit error rates that are essential for the high-quality video that consumers demand. Achieving such high performance requires relatively large encoding blocks. DVB-S2 uses a concatenation of Low-Density Parity Codes (LDPC) and BCH codes. These methods are computationally intense, especially for decoding. This doesn't matter much when Application Specific Integrated Circuits (ASIC) with volumes in tens of millions are involved. This is the normal case for Set Top boxes and other high-volume consumer products that are the targets for DVB-S2 receivers. It's a big problem, however, when using FPGA's that have costs proportional to resources.

The resource requirements for an FEC decoder also rise with the bit rate. While it is relatively easy for a receiver to synchronize to and demodulate high symbol rates, the FEC decoding process at such high rates requires lots of resources. These resources are wasted when the receiver only needs to decode a small portion of the bandwidth.

## 7.1 Systematic Codes

The BCH and LDPC codes used in DVB-S2 are so-called "systematic codes." This means that the raw data is present in the bit stream. Essentially, the FEC frame has a copy of the original data followed by a set of outer BCH code words that can be used to correct that data. This is followed by inner LDPC code words that can be used to correct the raw data together with their BCH codes.

When handling TV or TCP/IP streams, the robust FEC is always required. A single bit error not corrected either destroys the compressed video quality or requires that the IP packet be dropped. For isochronous digitized voice, however, we can tolerate a few bit errors or lost packets.

## 7.2 Ignoring and Enhancing FEC

Depending on the specific resources available in the terminal, we can 1) ignore the DVB-S2 FEC, 2) correct using just the outer BCH code, or 3) correct using the LDPC and BCH. In addition, we have the option of adding another level of FEC on the few bytes of data that matter for a single conversation. As the DVB-S2 FEC codes are systematic and the satellite channel is close to an AWGN channel, the error probabilities on individual bits are more or less independent. A relatively simple interleaved Golay code may be all that we need to recover our data to the extent required. For voice and text, we always have an additional final layer of forward error correction by that 100 giga-neuron neural-net processor between our ears.

Ignoring FEC does require that we use great care in how we construct the packets that carry narrowband voice data. Fortunately, this is straightforward. The narrowband digital voice and low rate data can be carried in GSE packets that contain an isochronous stream of UDP/IP packets that appear in a regular fashion in the stream. These carefully crafted UDP/IP packets can then be processed by receivers with or without DVB-S2 FEC.

## 8. Time Slicing

The previously described approach for narrowband services does not achieve everything needed for P4B. It works only for the narrow case of isochronous UDP/IP transport of digitized voice for which it is being proposed. We still need to use FEC protected streams to pass regular IP, particularly TCP connections.

In the commercial sector, the high data rates required for Ultra HD Television (UHDTV) are driving transponder bandwidths and symbol rates to higher and higher levels. These wideband transponders can have bandwidths from 72 MHz to hundreds of megahertz. While demodulators can keep up with these high symbol rates, the task of FEC decoding in real time for an entire symbol stream requires computational

resources significantly beyond those required for modulation alone.

Most applications do not need to decode the full bandwidth of the wide band carrier – just the streams for the services of interest. Requiring an FEC decoding capability for the full carrier bandwidth is uneconomic for many applications. The optional features of Annex M time-slicing are the Standard DVB-S2(X) solution to this need.

Annex M is designed to permit relatively low-cost receivers to process a full wide band carrier (72 MHz – 300 MHz for example) without having to FEC decode all of the bits in the stream. Instead, a receiver demodulates the carrier, but only FEC decodes the time-slots that it needs. While Annex M is designed for carriers on the order of hundreds of Mbps and timeslot streams on the order of tens of Mbps, it can also be used for the slower P4B application. In this case, Annex M could be used to reduce the workload of low-cost terminals.

## 8.1 Modified PLHEADER

Annex M modifies and expands the normal single slot PLHEADER to two slots. This allows the header to carry an additional 16 bits that specify a time-slice. A particular PLFRAME belongs to a single time-slice, and all of the time-slices in use are interleaved in whatever pattern is appropriate for the services offered. The MODCODs available are also expanded somewhat with additional choices made available as the result of the additional available bits.

With Annex M time slicing, a receiver essentially grabs the time slots that it needs while ignoring the rest. No FEC decoding is required for the frames of unneeded time slices. When the slices are adequately spaced, the bit rate required for the FEC decoder is well below that required for the entire stream. This lets a receiver operate with a 200Msym/s rate with an FEC decoder that provides only 20 Mbit FEC performance. In the case of P4B, the symbol rate is already a relatively modest (for an ASIC or high-end FPGA) rate of 10 Msym/s. However, a particular receiver may only need to process a more modest 1 Mega-symbols per second. This could be achieved with a much smaller FPGA and/or general purpose PC.

Unfortunately, Annex M must be applied to the entire carrier. It is a minor change to the header, but all stations using the carrier must support it. Because of its advantages, it is likely that most future ASIC's will be supporting Annex M and will be able to sync on either Normal or Annex M carriers.

Annex M is, therefore, a reasonable choice for P4B.

## 9. Summary

DVB-S2X and its Annex M provide a rich set of features that can be exploited in the design of Terminals, Satellites, and services for GEO satellites in the Amateur Radio Satellite Service. The Amateur Radio community has a long history of expropriating and repurposing technologies for different application and finding new ways of doing thing better and cheaper. The AMSAT ASCENT and Phase 4 Ground Teams are actively carrying on this tradition as Amateur Radio moves to GEO and beyond.

This paper has just touched on some ideas on the downlink. Many more innovations large and small are yet to come for downlinks, uplinks, the in-between, and the all around. These are exciting times for Amateur Radio.

## Footnotes

1 AMSAT P4A a separate 250 kHz linear transponder that supports narrowband analog signals.
2 ETSI EN 302 30101: Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications; Part 1: DVB-S2
3 ETSI EN 302 307-2: Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications: Part 2: DVB-S2 Extensions (DVB-S2X).
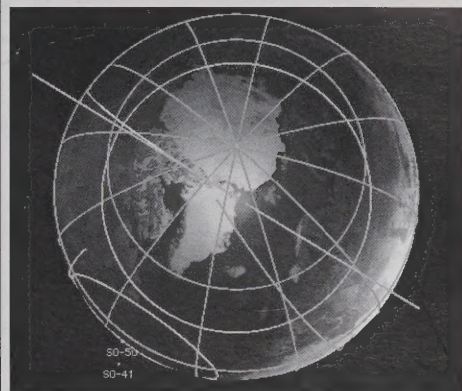4 ETSI TS 102 606-1: Digital Video Broadcasting (DVB); Generic Stream Encapsulation (GSE); Part 1: Protocol.
5 When Annex-M is used, this is extended to 180 symbols.
6 32,400 is added as a choice in the DVB-S2X standard for certain coding rates. ⊕

# Support AMSAT

**AMSAT is the North American distributor of SatPC32, a tracking program for ham satellite applications. For Windows 98, NT, ME, 2000, XP, Vista, Windows 7, 8/8.1 & 10.**

Version 12.8c is compatible with Windows 7, 8/8.1 & 10 and features enhanced support for tuning multiple radios.

## Version 12.8c features:

- SatPC32, SatPC32ISS, Wisat32 and SuM now support rotor control of the M2 RC-2800 rotor system.

- The CAT control functions of SatPC32, SatPC32ISS and Wisat32 have been expanded. The programs now provide CAT control of the new Icom transceiver IC-9100.

- The main windows of SatPC32 and SatPC32ISS have been slightly changed to make them clearer. With window size W3 the world map can be stretched (only SatPC32).

- The accuracy of the rotor positions can now be adjusted for the particular rotor controller. SatPC32 therefore can output the rotor positions with 0, 1 or 2 decimals. Corrections of the antenna positions can automatically be saved. In previous versions that had to be done manually.

- The tool "DataBackup" has been added. The tool allows users to save the SatPC32 program data via mouse click and to restore them if necessary. After the program has been configured for the user's equipment the settings should be saved with 'DataBackup'. If problems occur later, the program can easily restore the working configuration.

- The rotor interfaces IF-100, FODTrack, RifPC and KCT require the kernel driver IOPort.SYS to be installed. Since it is a 32-bit driver it will not work on 64-bit Windows systems. On such systems the driver can cause error messages. To prevent such messages the driver can now optionally be deactivated.

- SuM now outputs a DDE string with azimuth and elevation, that can be evaluated by client programs. Some demo files show how to program and configure the client.

Minimum Donation is $45 for AMSAT members, $50 for non-members, on CD-ROM.
A demo version may be downloaded from http://www.dk1tb.de/indexeng.htm
A registration password for the demo version may be obtained for a minimum donation of $40 for members and $45 for non-members.
Order by calling 1-888-322-6728.

The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.

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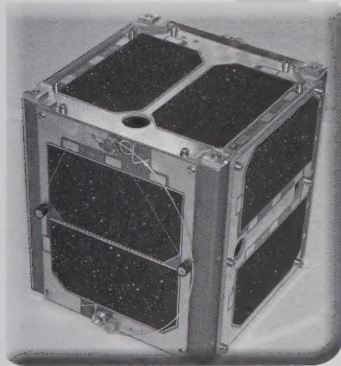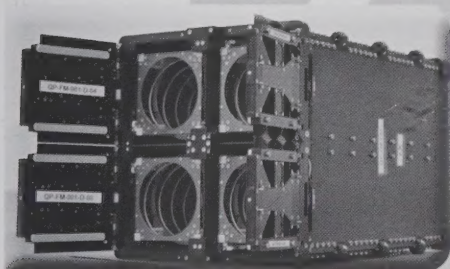
Our editors are standing by!

# AMSAT Fox-1Cliff & Fox-1D $125,000 Launch Initiative Goal

AMSAT is excited to announce a launch opportunity for **BOTH** the Fox-1Cliff and Fox-1D Cubesats. In response to a breaking opportunity, AMSAT and Spaceflight, Inc. have arranged for Fox-1D to accompany Fox-1Cliff on the maiden flight of the SHERPA system on a SpaceX Falcon 9 in the 1st quarter of 2016.

Fox-1Cliff and Fox-1D will provide selectable U/V or L/V repeater capabilities on separate frequencies once in orbit, and will be capable of downlinking Earth images from the Virginia Tech camera experiment.

AMSAT has an immediate need to raise funds to cover both the launch contract and additional materials for construction and testing for Fox-1Cliff and Fox-1D. We have set a fundraising goal of $125,000 to cover these expenses over the next 12 months, and allow us to continue to keep amateur radio in space.

**Spaceflight's SHERPA will deploy multiple cubesat payloads on-orbit**

**ISIS QuadPack Nanosatellite Dispenser**

Donations may be made through the AMSAT webpage at www.amsat.org, by calling (888) 322-6728 or by mail to the AMSAT office at 10605 Concord Street, Kensington, MD 20895, USA. Please consider a recurring, club, or corporate donation to maximize our chance of success with this mission.

## AMSAT President's Club
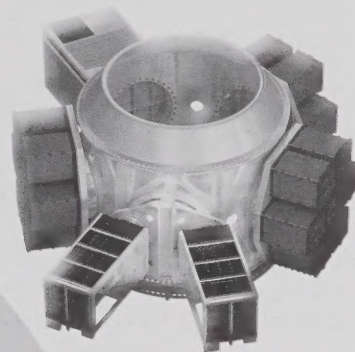## Support Fox-1Cliff and Fox-1D

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- Hardware development for spaceflight and ground stations
- Help with QSL and awards certificate mailing.

To volunteer send an e-mail describing your area of expertise to Frank Bauer at: **ka3hdo@amsat.org.**

### AMSAT Internet Presence

AMSAT's information technology team has immediate needs for volunteers to help with development and on-going support of our internet presence
:

- Satellite status updating and reporting.
- Add/delete satellites to ANS and the web as needed.
- Research and report satellite details including frequencies, beacons, operating modes.
- Manage AMSAT's Facebook and Twitter presence.

To volunteer, send an e-mail to Drew Glasbrenner, KO4MA at: ko4ma@amsat.org.

### AMSAT Engineering Team

AMSAT Engineering is looking for hams with experience in the following areas:

- Attitude Determination and Control, and Thermal Engineering, to help in the design of high orbit CubeSats.
- Power systems, for CubeSats from 1U through 6U and LEO to HEO.
- Help with solar, power supply, and battery design for both LEO and HEO missions.
- Logistics, for parts procurement, inventory, and distribution.
- Documentation, for designs, tests, and public relations.

To volunteer, please describe your expertise using the form at **ww2. amsat.org/?page_id=1121.**

### AMSAT User Services

AMSAT is looking for an on-line store co-manager to update and refresh the AMSAT Store web page when new merchandise becomes available or prices and shipping costs change.

- Add new merchandise offerings
- Delete merchandise no longer available
- Update shipping costs as needed
- Add periodic updates for event registrations
- Interface with the AMSAT Office

To volunteer, send an e-mail to Joe Kornowski, KB6IGK at: **kb6igk@ amsat.org**

### AMSAT Educational Relations Team

AMSAT's Educational Relations Team needs volunteers with a background in education and classroom lesson development ...

- Engage the educational community through presentations of how we can assist teaching about space in the classroom.
- Create scientific and engineering experiments packaged for the classroom.
- Create methods to display and analyze experimental data received from Fox-1.

To volunteer send an e-mail describing your area of expertise to Joe Spier, K6WAO at: **k6wao@amsat.org.**

### AMSAT Field Operations

AMSAT's Field Operations Team is looking for satellite operators to promote amateur radio in space with hands-on demonstrations and presentations.
- Promote AMSAT at hamfests.
- Setup and operate satellite demonstrations at hamfests.
- Provide presentations at club meetings.
- Show amateur radio in space at Dayton, Pacificon, Orlando Hamcation.

To volunteer, send an e-mail to Patrick Stoddard, WD9EWK at: **wd9ewk@amsat.org**

**You can find more information on the web: www.amsat.org – click AMSAT – then click Volunteer**